Radiological Health Data

VOLUME III, NUMBER 12

DECEMBER 1962

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis and interpretation of data on environmental radiation levels. The Department delegated this responsibility to the Division of Radiological Health, Public Health Service.

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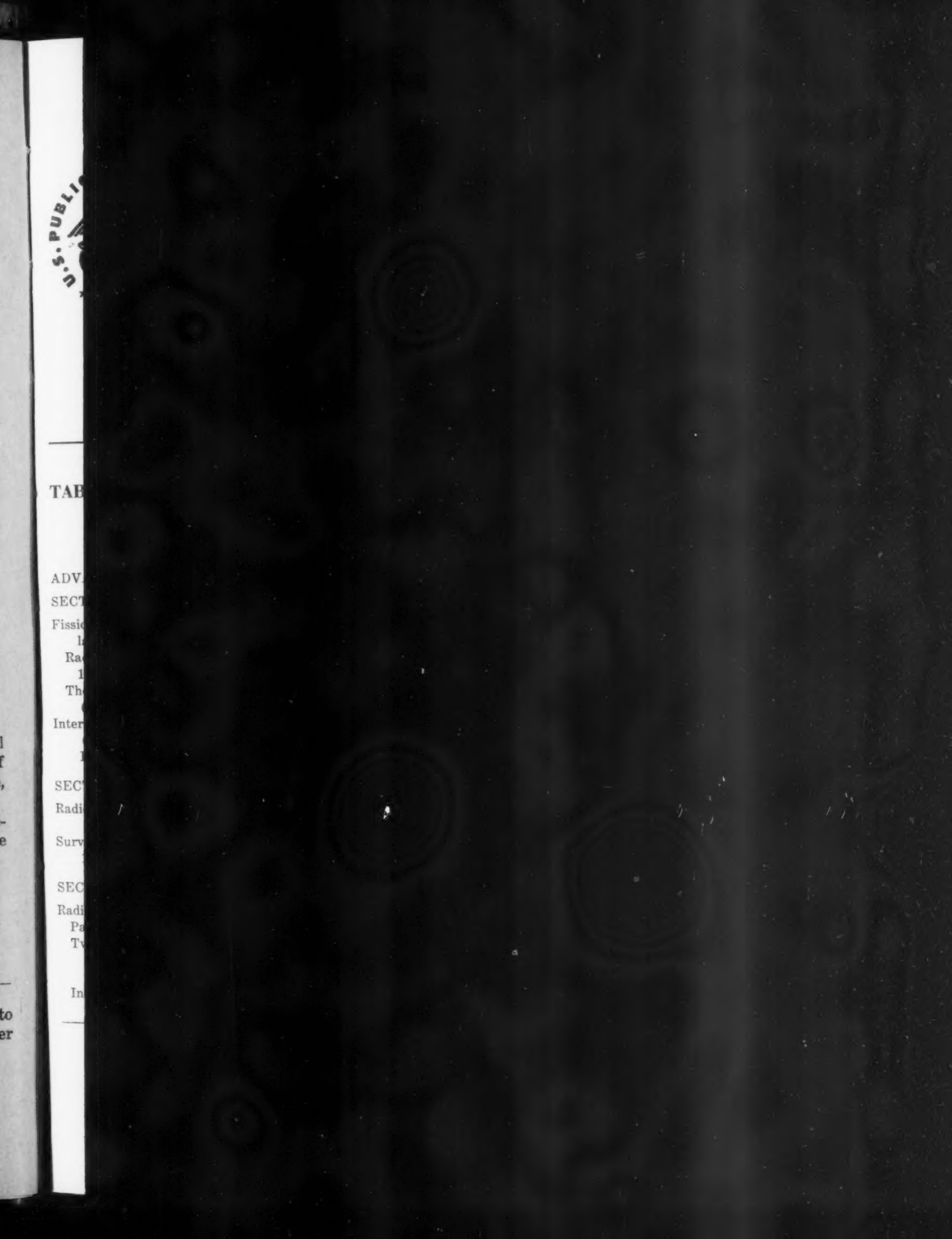

RADIOLOGICAL HEALTH DATA

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

ADVANCE REPORT

Reports during November 1962 to the Public Health Service Radiation Surveillance Center continued to indicate widespread occurrence of fresh fallout over the continental United States, Alaska, and Hawaii.

The Radiation Surveillance Network daily reported field estimates of gross beta radioactivity in air show levels rising over most of the United States the first part of November, reaching a peak on the 12th with generally higher levels in the West and South. Highest gross beta field estimates reported on the 12th were Denver, Colorado—170 $\mu\mu c/m^3$; Cheyenne, Wyoming—134 $\mu\mu c/m^3$; Santa Fe, New Mexico —101 $\mu\mu c/m^3$; and Salt Lake City, Utah—98 $\mu\mu c/m^3$. Air levels declined until November 23 when they again rose, reaching a peak in the Northwest States on the 25th and in the South Central and Southeastern States on the 26th with field estimates of 422 $\mu\mu c/m^3$ at Austin, Texas and 115 $\mu\mu c/m^3$ at New Orleans, which declined to 12 and 4 respectively by November 30th. During the latter part of the month, peak air readings for other areas of the country were: Berkeley, California—76 $\mu\mu c/m^3$ on the 25th; Miami, Florida—43 $\mu\mu c/m^3$ on the 27th; Portland, Oregon—42 $\mu\mu c/m^3$ on the 25th; and Concord, New Hampshire—43 $\mu\mu c/m^3$ on the 30th.

The general rise of radioactive air levels during the first two weeks of November was also reflected by a rise in gross beta radioactivity in precipitation. Most precipitation samples contained relatively young fission products (15–40 days as determined by the Way-Wigner method).

During November the Public Health Service's Pasteurized Milk Network monthly tabulation of the Network's 62 stations showed an average daily iodine–131 concentration of 70 $\mu\mu c$/liter. The October monthly average was 60 $\mu\mu c$/liter.

Fifty-three stations were above 20 $\mu\mu c$/liter compared to 46 stations during October. Of these 53 stations the following 11 stations had November monthly averages for iodine–131 of 100 $\mu\mu c$/liter or more:

Station	$\mu\mu c$/liter of milk	Station	$\mu\mu c$/liter of milk
Little Rock, Arkansas	100	Oklahoma City, Oklahoma	100
Wilmington, Delaware	140	Philadelphia, Pennsylvania	130
Des Moines, Iowa	120	Pittsburgh, Pennsylvania	170
Louisville, Kentucky	130	Memphis, Tennessee	100
Kansas City, Missouri	140	Milwaukee, Wisconsin	100
Cincinnati, Ohio	140		

SECTION I.—AIR AND PRECIPITATION

Fission Product Beta Activity in Airborne Particulates and Precipitation

Measurements of gross beta activity of airborne particulates and precipitation are among the earliest and most sensitive indicators of increases of fission product activity in the environment. However, a direct evaluation of biological effects is not possible from these data alone.

Of the several networks or sampling programs making such measurements, the Radiation Surveillance Network and the 80th Meridian (West) Sampling Program are represented in the following reports.

RADIATION SURVEILLANCE NETWORK
September 1962

Division of Radiological Health, Public Health Service

The Public Health Service Radiation Surveillance Network (RSN) was established in 1956 in cooperation with the Atomic Energy Commission primarily to provide a means of promptly monitoring increased levels of radioactivity in air and precipitation due to fallout from nuclear weapons tests. Prior to September 1961, the Network consisted of 45 stations. Following the September 1961 resumption of nuclear weapons testing by the U.S.S.R., the Network was expanded over a period of several months to 72 stations, whose locations are shown in figure 1.

Air

Daily 24–hour air samples are collected by a high volume air sampler with a 4–inch diameter carbon–loaded cellulose dust filter. Field measurements with a portable survey meter enable the station operator to estimate the amount of beta activity in airborne particulates at the station 5 hours after collection by comparison with a known Sr^{90}–Y^{90} source. This 5–hour delay eliminates interference from naturally–occurring radon daughters. Each operator then reports his field estimate by telephone to the Radiation Surveillance Center, Division of Radiological Health, Washington, D.C., to provide a daily national report.

The filters are then forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, for a more refined measurement using a thin–window gas–flow proportional counter. Each filter is counted after at least 3 days have elapsed from the end of the sampling period and is re–counted seven days later. The initial 3–day aging of the sample eliminates interference from naturally–occurring radon and thoron daughters. The two counts, separated by a 7–day interval, make possible the estimation of the age of fission products and extrapolation of the activity to the time of collection. The extrapolation is performed by using the Way–Wigner formula ($AT^{1.2} = \text{constant}$).[1]

[1] In this expression, A is the activity at time T after fission product formation. Units are arbitrary.

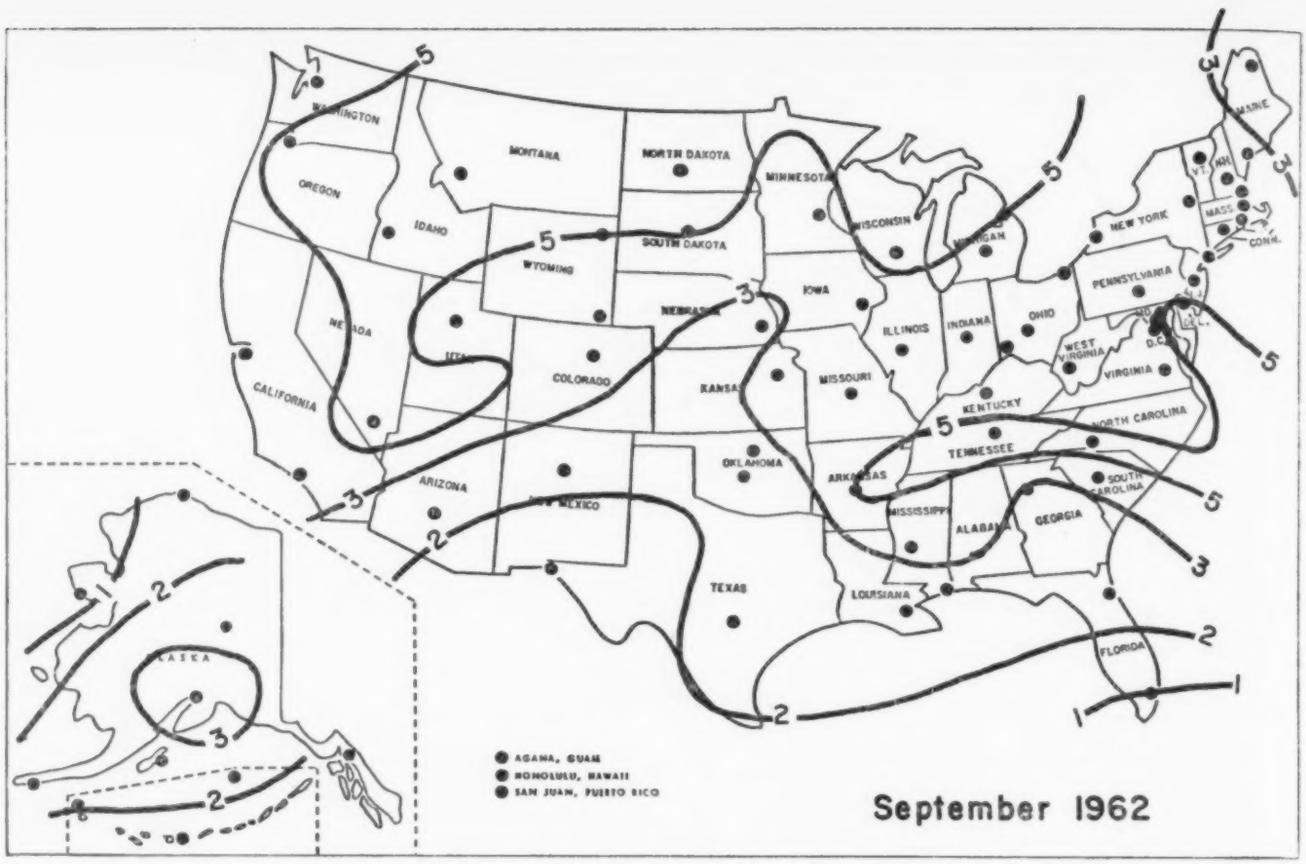

Figure 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS AND AVERAGE FISSION PRODUCT BETA CONCENTRATIONS IN AIR ($\mu\mu c/m^3$) SEPTEMBER 1962

Although gross beta concentration is usually presented without reference to age, it is apparent that fission product activity is more adequately described when the age parameter is also given. Because of the difficulty in determining a meaningful monthly average age of fission products, such data have not yet been presented with RSN data in *RHD*.

The average fission-product beta concentrations in surface air during September 1962 as determined by laboratory analysis are tabulated in table 1 and presented by means of concentration contours in figure 1.

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis using funnels having collection areas of 0.4 m^2. A 500–ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory to be counted by the same method used for analyzing the air samples. If the collected sample is between 200 and 500 ml, the entire sample is evaporated; if less than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

The September 1962 averages of gross beta activity in precipitation, expressed in micromicrocuries per liter ($\mu\mu c$/liter) and millimicrocuries per square meter ($m\mu c/m^2$) are presented in table 2.

Profiles

The profiles of the monthly average fission product beta activity in airborne particulates for each RSN station covering the period of time from the formation of the network in 1956 to the end of 1960 were published in *RHD*, July 1961. The profiles of 7 stations, updated through September 1962 are shown in figure 2.

TABLE 1.—RADIOACTIVITY OF PARTICULATES IN AIR, RSN, SEPTEMBER 1962

Station location		Number samples	Maximum	Minimum	Average[a]
Alaska:	Adak	30	7.2	<0.10	1.9
	Anchorage	30	36	0.17	3.4
	Attu	30	5.5	0.30	2.0
	Fairbanks	20	26	0.30	2.9
	Juneau	20	8.8	0.46	2.4
	Kodiak	29	12	<0.10	2.8
	Nome	28	3.2	<0.10	0.6
	Point Barrow Isl	24	3.4	<0.10	1.2
	St. Paul Island	23	30	0.17	2.3
Ariz:	Phoenix	30	13	0.46	2.5
Ark:	Little Rock	30	19	0.18	5.0
Calif:	Berkeley	30	17	0.27	4.0
	Los Angeles	18	8.9	0.71	3.6
Colo:	Denver	29	20	0.75	4.9
Conn:	Hartford	27	14	0.33	3.5
Del:	Dover	17	23	0.40	5.9
D.C:	Washington	30	12	0.33	4.0
Fla:	Jacksonville	28	7.0	<0.10	2.3
	Miami	29	4.8	0.23	1.0
Ga:	Atlanta	29	8.9	0.35	3.0
Guam:	Agana	—	—	—	—
Hawaii:	Honolulu	30	2.7	0.33	1.2
Idaho:	Boise	29	18	1.8	5.6
Ill:	Springfield	30	16	0.58	4.3
Ind:	Indianapolis	29	16	1.0	3.9
Iowa:	Iowa City	30	12	0.33	4.3
Kans:	Topeka	30	15	0.17	3.4
Ky:	Frankfort	28	14	0.70	4.0
La:	New Orleans	30	11	0.32	2.3
Maine:	Augusta	30	14	0.28	3.5
	Presque Isle	30	9.3	<0.10	2.7
Md:	Baltimore	30	13	0.55	4.6
	Rockville	16	10	0.87	5.7
Mass:	Lawrence	30	11	<0.10	3.1
	Winchester	29	11	0.21	3.8
Mich:	Lansing	29	15	0.48	4.8
Minn:	Minneapolis	30	9.8	0.18	3.9
Miss:	Jackson	30	15	0.29	3.7
	Pascagoula	15	19	0.34	2.4
Mo:	Jefferson City	30	14	0.49	4.0
Mont:	Helena	30	39	0.53	8.3
Nebr:	Lincoln	14	7.1	0.20	2.1
Nev:	Las Vegas	16	28	0.59	6.7
N.H:	Concord	18	11	0.14	4.1
N.J:	Trenton	30	11	0.30	3.4
N. Mex:	Santa Fe	29	11	0.52	2.3
N. Y:	Albany	30	12	0.26	4.0
	Buffalo	30	14	0.36	4.4
	New York	15	7.6	0.45	3.9
N. C:	Gastonia	30	12	0.91	5.1
N. Dak:	Bismarck	29	21	0.21	6.2
Ohio:	Cincinnati	8	10	1.5	4.6
	Columbus	29	15	0.79	4.5
	Painesville	30	16	0.39	4.8
Okla:	Oklahoma City	28	9.2	0.23	2.6
	Ponca City	27	3.6	0.21	1.3
Ore:	Portland	30	19	0.57	5.9
Pa:	Harrisburg	27	11	0.18	3.7
P. R:	San Juan	27	1.6	0.22	0.8
R. I:	Providence	30	17	0.24	4.3
S. C:	Columbia	28	8.4	0.50	3.1
S. Dak:	Pierre	29	13	<0.10	5.0
Tenn:	Nashville	27	19	0.39	5.8
Tex:	Austin	30	10	0.28	2.6
	El Paso	29	3.1	0.18	1.1
Utah:	Salt Lake City	30	15	0.70	4.6
Vt:	Barre	30	10	0.66	4.0
Va:	Richmond	30	7.8	0.32	3.9
Wash:	Seattle	29	7.7	0.67	3.2
W. Va:	Charleston	30	9.5	0.81	3.9
Wis:	Madison	30	18	0.81	5.7
Wyo:	Cheyenne	30	12	0.33	4.3
Network Average					3.7

[a] Weighted average obtained by summing the products of individual sampling times and the corresponding activities, and dividing by the summation of the individual sampling times.

TABLE 2—GROSS BETA ACTIVITY IN PRECIPITATION, RSN, SEPTEMBER 1962

Station location		Average concentration ($\mu\mu c$/liter)	Total deposition (mμc/m^2)
Alaska:	Adak	2,300	6.9
	Anchorage	3,600	150
	Attu	*	*
	Fairbanks	*	*
	Juneau	2,800	650
	Kodiak	*	*
	Nome	*	*
	Point Barrow Isl	*	*
	St. Paul Island	*	*
Ariz:	Phoenix	*	*
Ark:	Little Rock	430	76
Calif:	Berkeley	*	*
	Los Angeles	*	*
Colo:	Denver	*	*
Conn:	Hartford	1,100	84
Del:	Dover	*	*
D. C:	Washington	2,300	160
Fla:	Jacksonville	470	51
	Miami	2,800	700
Ga:	Atlanta	400	22
Guam:	Agana	*	*
Hawaii:	Honolulu	*	*
Idaho:	Boise	1,100	11
Ill:	Springfield	530	14
Ind:	Indianapolis	520	36
Iowa:	Iowa City	420	3
Kans:	Topeka	560	61
Ky:	Frankfort	450	31
La:	New Orleans	380	40
Maine:	Augusta	740	69
	Presque Isle	750	54
Md:	Baltimore	840	8.4
	Rockville	*	*
Mass:	Lawrence	780	100
	Winchester	2,200	145
Mich:	Lansing	1,000	53
	Minneapolis	1,200	93
Miss:	Jackson	400	10
	Pascagoula	*	*
Mo:	Jefferson City	440	59
Mont:	Helena	3,800	52
Nebr:	Lincoln	430	21
Nev:	Las Vegas	*	*
N. H:	Concord	*	*
N. J:	Trenton	*	*
N. Mex:	Santa Fe	770	46
N. Y:	Albany	760	20
	Buffalo	1,100	36
	New York	*	*
N. C:	Gastonia	360	34
N. Dak:	Bismarck	2,600	49
Ohio	Cincinnati	*	*
	Columbus	1,100	150
	Painesville	1,700	270
Okla:	Oklahoma City	400	25
	Ponca City	570	48
Ore:	Portland	660	12
Pa:	Harrisburg	700	39
P. R:	San Juan	390	710
R. I:	Providence	1,100	81
S. C:	Columbia	460	48
S. Dak:	Pierre	1,300	13
Tenn:	Nashville	340	32
Tex:	Austin	440	35
	El Paso	410	32
Utah:	Salt Lake City	1,100	17
Vt:	Barre	840	68
Va:	Richmond	670	47
Wash:	Seattle	2,400	92
W. Va:	Charleston	650	40
Wis:	Madison	1,200	29
Wyo:	Cheyenne	1,100	36

* Indicates no evaporated sample received.

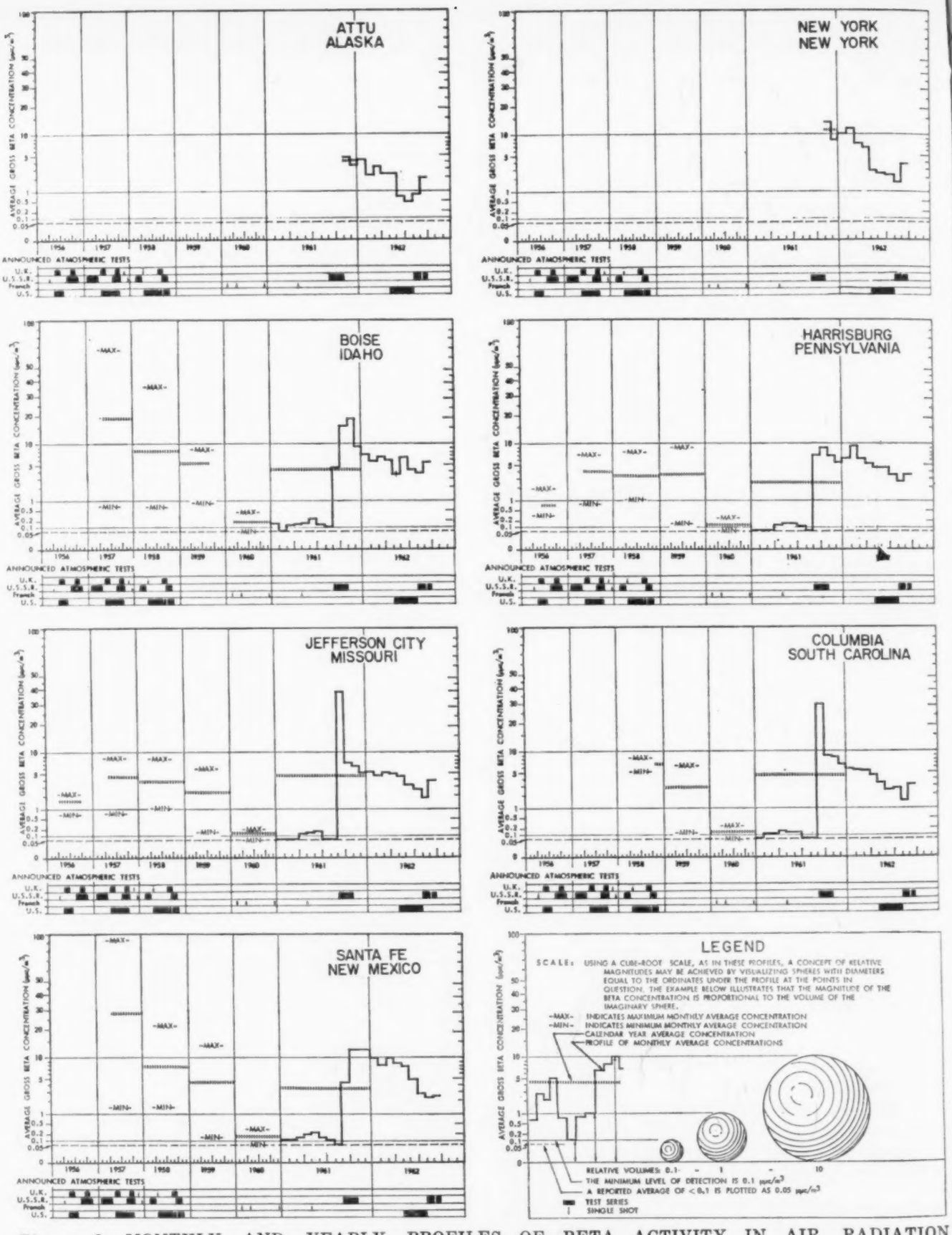

Figure 2.—MONTHLY AND YEARLY PROFILES OF BETA ACTIVITY IN AIR, RADIATION SURVEILLANCE NETWORK, 1956–SEPTEMBER 1962

THE 80TH MERIDIAN (WEST) SAMPLING PROGRAM
August 1962

U.S. Naval Research Laboratory

Radioactivity measurements of surface air samples collected at various sites near the 80th Meridian (West) have been made since 1956. Sampling locations are shown in figure 3. This program is operated by the U.S. Naval Research Laboratory (NRL) with the cooperation of interested agencies of the United States, Canada, Ecuador, Peru, Bolivia, and Chile, which collect the samples and forward them to NRL for analysis. Partial financial support of this program is provided by the Division of Biology and Medicine, U.S. Atomic Energy Commission.

The sampling procedure involves drawing air continuously for a 7–day period, at a rate of approximately 1200 cubic meters per day, through an 8–inch diameter, high–efficiency filter, using a positive–displacement blower. After the 7–day period, the filter is removed and forwarded to NRL for assay of gross beta activity. A minimum of 2 weeks after collection is allowed for decay of short–lived radionuclides. Data are not extrapolated to time of collection.

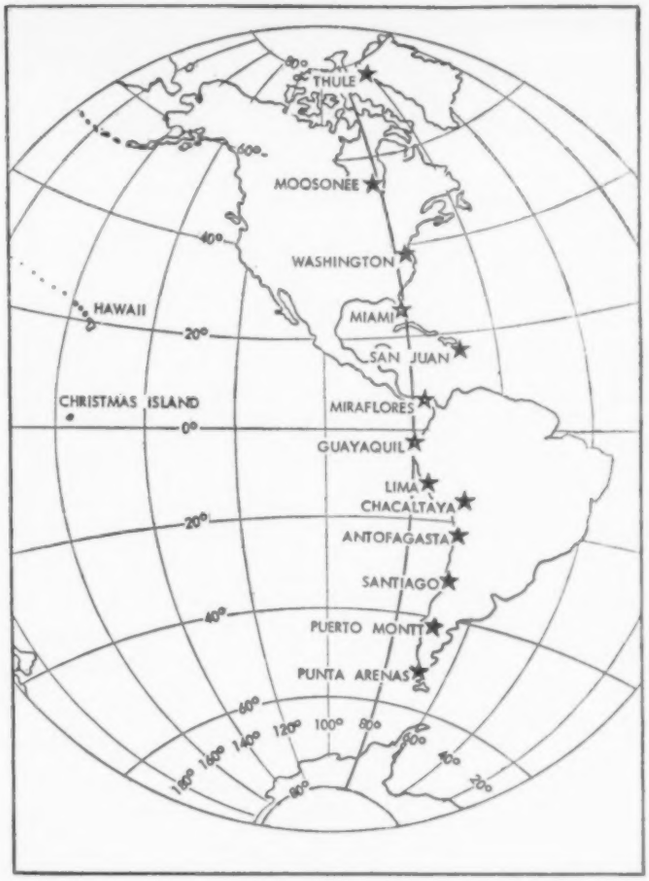

Figure 3.—ATMOSPHERIC RADIOACTIVITY SAMPLING STATIONS NEAR THE 80TH MERIDIAN (WEST)

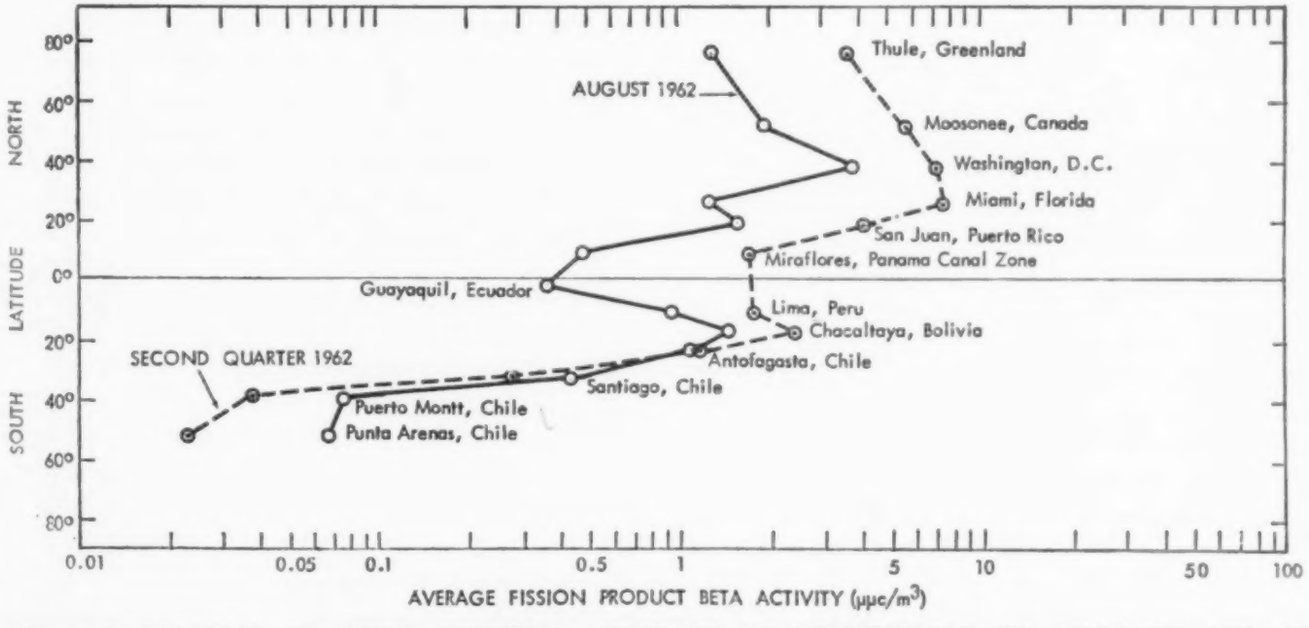

Figure 4.—PROFILE OF BETA ACTIVITY, AVERAGE MEASUREMENTS OF SURFACE AIR AT STATIONS NEAR THE 80TH MERIDIAN (WEST) AUGUST 1962

TABLE 3.—FISSION PRODUCT GROSS BETA ACTIVITY IN SURFACE AIR, NRL[a], AUGUST 1962

[Average concentrations in $\mu\mu c/m^3$]

Day	Punta Arenas, Chile	Puerto Montt, Chile	Santiago, Chile	Antofagasta, Chile	Chacaltaya, Bolivia	Lima, Peru	Guayaquil, Ecuador	Miraflores, Panama Canal Zone	San Juan, P. R.	Mauna Loa, Hawaii[b]	Miami, Florida	Washington, D. C.	Moosonee, Ontario Canada	Thule, Greenland
1 2 3 4 5 6	0.067	0.067	[c]—	1.49	1.64	1.42	0.495	0.756	1.62	1.81	2.28	3.96	2.21	2.24
7 8 9 10 11 12 13	0.035	0.087	—	0.994	—	0.698	0.269	0.630	1.78	1.84	1.12	—	1.69	1.28
14 15 16 17 18 19 20	0.058	0.082	— / 0.603	0.869	—	0.760	0.328	0.413	1.78	1.64 / —	1.32	3.28	1.41	0.327
21 22 23 24 25 26 27	0.117	0.082	0.291	1.26	1.36	0.882	0.326	0.285	1.05	—	0.832	3.44	2.28	1.27
28 29 30 31	0.030	0.080	0.430	0.90	1.26	0.954	0.404	0.167	1.41	—	0.639	5.00	2.60	1.45
Weighted average	0.064	0.080	0.432	1.11	1.44	0.927	0.357	0.468	1.53	1.78	1.26	3.78	1.98	1.27

[a] The average concentration determined from a given sample is placed at the center of a rectangle which indicates the length and dates of the sampling period. Station averages for the month were determined by weighting the sample average according to the number of days in the sampling period or that portion of the sampling period occurring in August 1962.

[b] Mauna Loa data have been included for comparison with Chacaltaya, Bolivia. Both are high elevation stations (3400 and 5200 meters) and about equally distant north and south of the equator.

[c] Dash indicates samples were not received.

Intercalibration of Some Air Monitoring Systems

L. B. Lockhart, Jr. and R. L. Patterson, Jr.[1]

Introduction

The various systems employed for monitoring fission products in the atmosphere, both in this country and abroad, have been developed more or less independently of each other and consequently often employ vastly different techniques for collection, evaluation, and standardization. These differences have been clearly apparent at those sites where two or more systems make concurrent collections as, for example, at Washington, D.C., and Moosonee, Canada where the NRL 80th Meridian Network coincides with the Public Health Service Radiation Surveillance Network and the Canadian Air Monitoring Network, respectively. The desirability of obtaining factors for directly comparing results obtained by any one network with those obtained by the others is obvious.

The U.S. Naval Research Laboratory, with the cooperation and active participation of the U.S. Public Health Service and the Radiation Protection Division of the Canadian Department of National Health and Welfare, undertook the collection of airborne fission products at Washington, D.C., through use of the standard equipment and procedures employed by the different systems (*1,2,3*). After preliminary evaluation for radioactivity, the exposed filters were returned to the parent organizations for evaluation by their customary procedures.

Experimental Procedures

Equipment from each of the systems was set up on the roof of a building at NRL and

[1] Dr. Lockhart is Head of the Physical Chemistry Branch, and Mr. Patterson is Head of the Radiochemistry Section, Physical Chemistry Branch, U.S. Naval Research Laboratory, Washington, D.C.

operated side-by-side for several months using filters supplied by the parent organizations and employing the normal operating procedures of each system. The characteristics of the various systems are compared in table 1. The sampling period during this study was generally 24 hours ending at 3:00 p.m. (1500) local time. Weekend collections were made with the 80th Meridian and Canadian systems which could operate unattended for this period of time.

Each of the collecting systems was calibrated for air flow against the same flow meter (Fischer and Porter, 55 CFM capacity) and the flow rate routinely recorded at the beginning and end of each collection.

On removal of the samples from the collector, one or more of them was followed for decay during a 16–hour period so that corrections for the presence of natural activity in the samples at the time they were evaluated at NRL (16–18 hours after collection) could be made (*4*). The samples were then forwarded to the parent organizations for measurement.

Some measurements were made in March and early April 1962 in a preliminary study of NRL and PHS collectors and counting techniques. Parallel operation of the samplers from the three operating networks was carried out during the period April 20–June 18, 1962. During this period the primary source of the fission product radioactivity in the air in the Washington area was the U.S.S.R. test series of 1961.

Results

The large quantity of data accumulated in this project is presented in detail elsewhere (*5*) and only a summary of the data and results is reported here.

The preliminary studies indicated that the two sampling systems, employing similar filters but different types of blowers, were adequately calibrated at NRL as to the volume of air sampled and that a major difference did exist in the volume calibration using the orifice plate and gage supplied by PHS. Furthermore, a consistent difference existed between the disintegration rates determined at NRL and PHS, most probably as a result of the different radioactive standards employed.

The results of the measurements made at NRL on the samples collected through use of the PHS, Canadian and 80th Meridian systems are summarized in table 2. The small standard deviation of single determinations of the activity ratios (less than 10%) indicates that each collector is effectively sampling the same air mass untroubled by recycling of filtered air. As far as effectiveness of sample collection is concerned, the Canadian and 80th Meridian systems are essentially identical while the PHS system shows a definitely lower effi-

TABLE 1.—CHARACTERISTICS OF THE AIR MONITORING SYSTEMS STUDIED IN THE INTERCALIBRATION PROGRAM

System elements	Radiation Surveillance Network U.S. Public Health Service	Air Monitoring Network Radiation Protection Division Canadian Dept. of Health and Welfare		80th Meridian Network U.S. Naval Research Laboratory
Air Sampler				
Blower, type	Centrifugal	Positive–displacement		Positive–displacement
Capacity*	40–46 CFM	17–24 CFM		26–29 CFM
Motor, type	Free running	Constant speed		Constant speed
Filter type	Cellulose, carbon–loaded	(a)	(b)	Cellulose/asbestos
		glass fiber	Polystyrene	
Designation	MSA BM–2133 (CR–17651)	Hurlburt 934AH	Microsorban (Gelman Instrument Co.)	Army Chemical Corps Type 6
Size (dia.)	4 inch	4 inch	4 inch	8 inch
Effective area	9.6 sq. inches	9.3 sq. inches	9.3 sq. inches	41.3 sq. inches
Volume measurement (at field stations)	Orifice plate and gage	Prior calibration		Prior calibration
Sample processing	Counted in glassine envelope	2 inch disc removed for counting		Ashed at 640°C Compressed to 1–1/8" dia. disc
Counting Procedure				
Counter, type—size (dia.)	Gas flow proportional—7½ inch	Gas flow Geiger—2 inch		Organic quenched Geiger—2 inch
Window thickness		0.8 mg/cm²		1.4 mg/cm²
Geometry	2π	2π		2π
Background	500 c/m	13 c/m		10 c/m
Counting time	1 min.	preset count of 900		Preset count of 10,000
Standard	Sr^{90} (Y^{90})	Sr^{90} (Y^{90})		Ra (D, E, and F)
Activity Recorded	Extrapolated to end of collection	Extrapolated to end of collection		At time of measurement (2 weeks after collection)

* As measured at NRL with clean filters in holder.

TABLE 2.—AIR MONITORING SYSTEMS ACTIVITY RATIOS EVALUATED AT NRL

Systems Compared	Number of Measurements	Mean of Measured Ratios	Standard Deviation		
			of Mean	of Single Measurement	
PHS Sampler / 80th Meridian Sampler	31	0.77	±0.013	±0.073	(9.5%)
PHS Sampler / Canadian Sampler	31	0.77	±0.013	±0.072	(9.4%)
Canadian Sampler / 80th Meridian Sampler	39	0.98	±0.010	±0.060	(6.1%)

ciency. This lower counting rate is entirely a function of the filter employed. The filter used by PHS has a lower measured retentivity for fission products and higher self-absorption due to deeper penetration of radioactive particles into the filter mat.

The activity concentrations reported by the parent organizations for the series of samples described above are listed in table 3. The uncorrected results presented are those that normally would have been reported by the network and are based either on an orifice plate and flow gage measurement (PHS) or on initial calibrations of the blower and filter systems (Canadian and 80th Meridian); the corrected results are based on the NRL air flow measurements. The calculated ratios listed are based on the corrected activity concentrations.

Though there is quite a spread in the activity concentrations obtained with the various systems, there appears to be a high degree of precision in the intercalibration ratios obtained. The relative activity concentrations determined by the three techniques are as follows: PHS, 0.65; Canada, 1.00; 80th Meridian, 1.12. The factors compared in this study do not indicate which system gives results that are nearest to the correct value. It is clear that the major source of disagreement between the various systems lies in the technique employed to standardize the counting equipment.

It is also recognized that the various systems will not have the same relative counting efficiency toward fission product mixtures of different beta energy distribution due either to self-absorption within the sample or to absorption by the counter window, and that some revision of the above intercalibration factors will be required when fresh fission debris is present. The usage of such varying factors would require a determination of the age of the debris in each individual collection; a more practical solution might be the experimental determination of the range of errors introduced in the above factors with nuclear debris of different ages.

The decreased precision in the measurements of the 80th Meridian samples, which require more processing and the counting of thick samples, is evident since the standard deviation of single measurements of activity ratios relative to 80th Meridian samples is higher than that of the other pairs of measurements. It appears that it would be reasonable to employ these activity concentration ratios to interconvert reported activities obtained from any one of these systems with a high degree of reliability, subject only to uncertainties in the volume of air sampled. This latter variable could easily be kept below 5 percent with a few precautions or simple measurements.

Conclusions and Recommendations

Realistic interconversion ratios for comparing radioactivity concentration data reported by several air monitoring networks have been derived which are subject to uncertainty only

TABLE 3.—AIR CONCENTRATIONS OF FISSION PRODUCT RADIOACTIVITY BASED ON ANALYSIS BY THE PARENT ORGANIZATION OF AIR FILTERS EXPOSED IN PARALLEL AT WASHINGTON, D. C.

Collection ending	Activity concentration ($\mu\mu c/m^3$) reported by[a]						Ratios of corrected activity concentration		
	USPHS		Canada		80th Meridian		PHS / Canada	PHS / 80th Meridian	Canada / 80th Meridian
	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.			
April 20	2.9	3.6	4.1	[b]4.1	4.97	4.35	0.71	0.58	0.82
21	[c]—	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—
24	4.7	5.9	7.0	[b]7.0	8.84	7.73	0.67	0.53	0.79
25	—	—	6.3	[b]6.1	9.36	8.10	—	—	0.67
26	5.5	6.9	8.1	[b]7.9	9.00	8.55	0.68	0.61	0.90
27	6.8	8.5	10.1	7.3	12.69	11.77	0.67	0.54	0.80
28	—	—	[d]7.7	[d]6.6	[d]12.68	[d]10.83	—	—	—
29	—	—	"	"	"	"	—	—	—
30	—	—	"	"	"	"	—	—	0.61
May 1	3.4	4.3	5.1	5.1	8.66	7.49	0.67	0.39	0.59
2	0.96	1.2	1.4	1.2	1.59	1.38	0.69	0.60	0.88
3	0.96	1.2	1.6	1.4	2.08	1.80	0.60	0.46	0.77
4	4.7	5.9	8.1	6.5	9.87	8.60	0.58	0.48	0.82
5	—	—	[d]8.1	[d]6.5	[d]9.82	[d]9.13	—	—	—
6	—	—	"	"	"	"	—	—	—
7	—	—	"	"	"	"	—	—	0.82
8	6.0	7.5	8.3	6.9	8.68	8.05	0.72	0.69	0.96
9	4.3	5.4	6.8	5.3	7.80	6.75	0.63	0.55	0.87
10	4.8	6.0	7.8	6.0	8.76	7.63	0.62	0.55	0.89
11	4.0	5.0	6.3	5.2	8.06	7.05	0.63	0.50	0.78
12	—	—	[d]7.2	[d]6.1	[d]8.53	[d]7.39	—	—	—
13	—	—	"	"	"	"	—	—	—
14	—	—	"	"	"	"	—	—	0.84
15	5.2	6.5	7.9	6.2	8.62	7.45	0.66	0.60	0.92
16	4.5	5.7	7.6	6.1	8.31	7.21	0.59	0.54	0.91
17	2.6	3.3	4.7	4.0	3.75	3.58	0.55	0.69	1.25
18	3.0	3.8	4.5	3.7	3.79	3.60	0.67	0.79	1.19
19	—	—	—	—	[d]7.24	[d]6.78	—	—	—
20	—	—	—	—	"	"	—	—	—
21	—	—	—	—	"	"	—	—	—
22	4.4	5.5	7.3	5.5	7.05	6.34	0.60	0.62	1.04
23	3.2	4.0	5.4	4.5	4.82	4.60	0.59	0.66	1.12
24	4.4	5.5	6.8	[b]8.0	7.05	6.87	0.65	0.62	0.96
25	4.7	5.9	6.8	[b]7.7	7.43	6.76	0.69	0.63	0.92
26	—	—	[d]5.9	[d]5.1	[d]8.35	[d]7.49	—	—	—
27	—	—	"	"	"	"	—	—	—
28	—	—	"	"	"	"	—	—	0.71
29	3.1	3.9	5.0	6.3	6.37	5.55	0.62	0.49	0.78
30	[d]2.7	[d]3.4	[d]3.9	[d]3.8	[d]3.83	[d]3.61	—	—	—
31	"	"	"	"	"	"	0.69	0.70	1.02
June 1	—	—	4.5	5.2	4.03	3.50	—	—	1.12
2	—	—	[d]4.1	[d]4.1	[d]5.73	[d]4.97	—	—	—
3	—	—	"	"	"	"	—	—	—
4	—	—	"	"	"	"	—	—	0.72
5	2.0	2.5	2.9	3.5	3.60	3.31	0.69	0.56	0.81
6	1.1	1.4	1.8	2.1	2.33	2.04	0.61	0.47	0.77
7	—	—	8.1	9.2	10.68	9.31	—	—	0.76
8	4.5	5.6	6.5	7.5	7.78	6.90	0.69	0.58	0.84
9	[d]6.1	[d]7.7	[d]8.3	[d]8.7	[d]7.79	[d]7.30	—	—	—
10	"	"	"	"	"	"	—	—	—
11	"	"	"	"	"	"	0.73	0.78	1.07
12	3.3	4.1	5.0	[b]5.7	5.69	5.13	0.66	0.58	0.88
13	0.74	0.93	1.3	[b]1.5	1.45	1.25	0.57	0.51	0.90
14	0.37	0.46	0.55	[b]0.65	0.68	0.60	0.67	0.54	0.81
15	2.6	3.2	4.5	[b]5.6	11.21	9.80	0.58	—	—
16	[d]6.2	[d]7.8	[d]9.1	[d]8.7	[d]11.03	[d]10.31	—	—	—
17	"	"	"	"	"	"	—	—	—
18	"	"	"	"	"	"	0.68	0.56	0.83
Average							0.65	0.58	0.87
Standard deviation of the mean							±0.009	±0.017	±0.024
Number of measurements							31	30	38
Standard deviation of a single measurement							±0.048 (7.4%)	±0.091 (15.7%)	±0.147 (16.9%)

[a] Uncorrected results that would have been reported following the normal procedure in use in the network. The corrected results include a volume correction based on the measured air flow through the filter.
[b] Indicates glass fiber filter used rather than Microsorban filter.
[c] Dash indicates no sample taken.
[d] Value shown represents continuous sample taken during the period including this date and one or two succeeding days shown by ditto marks.
[e] Sample contaminated; count disagrees markedly with preliminary evaluation.

in the quantity of air sampled at the various sites. The relative activity values obtained by the three networks are as follows: U.S. Public Health Service Radiation Surveillance Network, 0.65; Canadian Air Monitoring Network, 1.00; NRL 80th Meridian Network, 1.12.

The above interconversion factors have been determined for fission product mixtures whose major component was 6–8 months old. Some minor differences are to be expected when there is present in the air a fission product conglomerate consisting of younger debris, due to the varying counter response to the different beta spectra of old and young debris; of more importance is the fact that no correction for radioactive decay is applied to the 80th Meridian collections.

In order to better measure the volume of air sampled it would be highly desirable for all networks to employ positive displacement blowers driven by constant speed motors and for each unit to be equipped with a calibrated pressure gage which is read at the beginning and end of each collection. The use of one of a number of available filter media having essentially 100% retention for fission products at the face velocity employed in the sampling device is highly recommended.

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SECTION II.—FOOD

Radionuclides in Institutional Diet Samples

March 1962–June 1962

Division of Radiological Health, Public Health Service

The determination of radionuclide concentration in the diet constitutes an important element of an integrated program of environmental radiation surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. This program is being administered by the Division of Radiological Health with the assistance of the Division of Environmental Engineering and Food Protection (*1*).

The program is designed to estimate the dietary intake of radionuclides in a controlled population group ranging from children to young adults of school age. Initially, the program consisted of sampling diets in eight institutions, but it has since been expanded to 21 boarding schools or institutions, geographically distributed as shown in figure 1. Institutions selected range from exclusive, well–funded boarding schools to orphanages with severe economic limitations. Each institution (sampling point) is located in a community monitored by both the Pasteurized Milk Network and the Drinking Water Analysis Program. The analytical data from these two sampling activities are used to supplement the findings from the Institutional Diet Sampling Program.

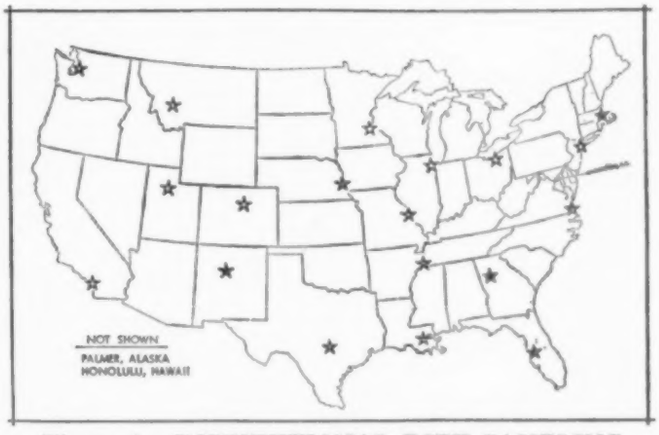

Figure 1.—INSTITUTIONAL DIET SAMPLING LOCATIONS, JUNE 1962

Sampling Procedure

In general, the sampling procedure is the same in each case. Each sample represents the edible portion of the diet for a full 7–day week (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Each institution supplies one complete 7–day, 21–meal diet sample each month. Meals are frozen following collection. On completion

of the total sample, it is packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nevada, the Southeastern Radiological Health Laboratory, Montgomery, Alabama, or the Northeastern Radiological Health Laboratory, Winchester, Massachusetts.

Each sample is packaged in three containers: one containing solid food less seed pits, rinds, shells, bones, etc. that would not ordinarily be eaten; one containing dairy products such as milk, cottage cheese, ice cream, etc.; and one containing soft drinks, coffee, tea, etc. A record of the contents of each meal and the approximate weight of each item is recorded by the institution's dietician and sent with the sample. Samples usually range from 6 to 16 liters in volume and weigh from 8 to 20 kilograms.

Analytical Program

Total weight, stable calcium, and stable potassium determinations are obtained by conventional gravimetric or spectrophotometric methods. Phosphate determinations are made by colorimetric technique. Because calcium and phosphorus compounds may have an effect on the uptake of important boneseeking radionuclides such as strontium–89 and strontium–90, they are included in the analytical program.

The radioanalysis program is designed around three basic procedures: (*1*) gamma spectroscopy, (*2*) chemical separation of strontium–89 and strontium–90 with subsequent counting, and (*3*) total radium analysis. In the absence of interference, other than naturally–occurring radioactive potassium (K^{40}), minimum detectable concentrations for the gamma scan on a per kilogram basis are: I^{131}, 10 μμc/kg; Cs^{137}, 5 μμc/kg; and Ba^{140}, 10 μμc/kg. Approximate minimum detectable concentrations for Sr^{89}, Sr^{90}, and total radium are: 5, 1, and 1 μμc/kg, respectively.

TABLE 1.—INSTITUTIONAL DIETARY INTAKE

Determination	Month (1962)	Alaska Palmer	California Los Angeles	Colorado Denver	Florida Tampa	Georgia Atlanta	Hawaii Honolulu	Illinois Chicago	Louisiana New Orleans	Massachusetts Boston
Total weight (kg/day)	Mar	1.67	1.41	2.24	1.69	1.70	2.00		2.04	2.41
	Apr	1.69	1.59	2.30	1.59	1.80	2.09	1.50	2.10	2.33
	May	1.36	1.79	2.02	1.65	1.48	2.24	1.68	2.03	1.93
	Jun	1.22		0.88	1.62	1.45	2.43	1.72	2.41	1.51
Calcium (g/day)	Mar	1.1	1.1	1.7	0.9	0.8	0.8		1.2	1.7
	Apr	1.5	0.7	2.3	1.1	1.1	0.8	0.8	1.3	1.7
	May	1.2	0.9	2.1	0.8	0.7	1.3	1.0	1.3	1.3
	Jun	0.6		1.8	0.9	0.7	0.7	0.6	1.4	0.4
Phosphorus (g/day)	Mar	4.6	3.9	6.3	3.9	3.4	3.2		4.1	5.4
	Apr	3.7	3.5	5.3	4.1	3.7	3.8	4.4	7.0	6.4
	May	3.8	3.8	5.6	4.1	3.4	5.3	4.5	4.1	3.7
	Jun	2.8		8.0	3.3	2.7	4.1	2.0	3.9	1.9
Potassium (g/day)	Mar	4.1	2.0	5.5	2.1	2.4	3.6		2.4	3.8
	Apr	3.0	3.0	4.5	2.4	2.3	2.3	2.3	2.7	3.7
	May	2.2	2.7	3.0	1.9	2.1	2.7	2.8	3.1	4.1
	Jun	1.6		2.9	1.9	1.5	3.2	3.9	3.3	3.1
Total Radium (μμc/day)	Mar	3.5	2.0	4.0	2.0	3.0	2.0		2.0	<3.0
	Apr	1.0	1.0	10.0	7.5	4.0	4.0	<2.0	4.0	<3.0
	May	1.0	2.0	14.0	<1.0	4.0	9.0	<2.0	<2.0	<2.0
	Jun	1.0		11.0	2.5	2.0	7.0	<1.0	<3.0	1.0
Strontium–89 (μμc/day)	Mar				<10	41			186	<15
	Apr				<10	126		<10	195	<15
	May			110	5	40	<5	35	145	<15
	Jun	35		55	<10	35	25	<5	160	5
Strontium–90 (μμc/day)	Mar	4	5	6	7	8	5		24	16
	Apr	16	3	8	9	16	9	4	25	11
	May	4	2	<1	4	12	<1	13	32	3
	Jun	5		20	8	10	17	3	36	2
Iodine–131 (μμc/day)	Mar	<10	<10	<10	<20	<20	<10		<20	<25
	Apr	<10	<10	<10	<20	<20	<10	<15	<25	<25
	May	<10	<10	30	<20	<20	90	30	<20	<15
	Jun	<10		<10	<20	<20	50	<10	<30	<10
Cesium–137 (μμc/day)	Mar	17	<5	22	20	41	40		49	21
	Apr	25	<5	<5	43	63	30	8	84	58
	May	5	<5	20	40	<10	55	20	130	68
	Jun	20		<5	<10	40	75	170	105	115
Barium–140 (μμc/day)	Mar	<10	<10	<10	<20	<20	<10		<25	<10
	Apr	80	<10	<10	<20	<20	<10	<15	<25	<25
	May	<10	<10	<10	<20	<20	110	<20	<20	<15
	Jun	<10		20	<20	<20	120	<10	<30	<10

Total radium is determined by ashing, separation, and coprecipitation of radium and barium as sulfate or chromate. After transfer to planchets, alpha activity is measured by an internal proportional counter with an appropriate delay for checking ingrowth of radium daughters. Since naturally–occurring radionuclides may contribute to the reported total radium values, the total radium technique is a practical screening indicator only. The bone dose, calculated by assuming total radium to be only radium–226 would therefore be moderately high. The acquisition of special equipment is projected to perform specific determinations of radium–226.

Data Treatment

Table 1 presents the dietary intake data expressed on a per–day basis from March 1962 through June 1962. Values previously published in *RHD* show the daily total ash and total water content of the samples.[1] As these items are not directly related to radionuclide intake, they are not reported. The reported iodine–131 values are the daily intake based on the iodine–131 content of the sample at the end of the sample collection period. The true iodine–131 intake may therefore be somewhat greater than the reported values.

Monthly network averages for strontium–89, strontium–90, iodine–131, cesium–137, and barium–140 are shown in figure 2. Certain of the radioanalyses are reported by the laboratories as being "less than" (<) a specified value. For data averaging, the convention employed is that all "less than" data are assumed to be equal to the full "less than" value. A

[1] Previous coverage in *Radiological Health Data*:

Period	Issue
January 1961–February 1962	*July 1962*

(BASED ON A 7 DAY COMPOSITE SAMPLE)

Minnesota Minneapolis	Missouri St. Louis	Montana Helena	Nebraska Omaha	New Mexico Albuquerque	New York New York	Ohio Cleveland	Tennessee Memphis	Texas Austin	Utah Salt Lake City	Virginia Norfolk	Washington Seattle	Network average
	3.01	2.34	2.03	1.37	1.60	1.47	1.74	2.69	1.07	1.47	2.76	1.93
1.70	3.20	2.44	1.74	1.70	1.53	1.73	2.39	2.99	1.26	1.90	2.83	2.04
1.60	2.93	2.71	1.57	1.70	1.74	1.60	1.94	3.08	1.57	1.23	2.73	1.93
1.53	3.24	2.55	1.76	1.50	1.40	1.94	1.65	2.95		1.83	2.79	1.91
	1.8	1.6	1.3	0.8	0.7	1.1	1.2	1.3	0.5	0.7	1.9	1.2
1.0	2.0	1.4	1.0	1.2	0.8	1.2	1.2	1.7	1.3	0.9	2.1	1.2
0.5	2.0	1.4	1.4	1.2	0.9	1.1	1.3	1.7	0.8	0.5	1.9	1.2
0.8	2.1	1.4	1.2	1.2	0.9	0.5	0.6	1.7		0.8	1.9	1.1
	8.2	6.4	5.3	3.1	3.0	3.6	4.1	5.6	2.3	3.0	7.9	4.6
3.9	7.3	5.1	3.6	3.8	3.3	3.7	3.9	7.8	3.4	4.0	6.7	4.7
2.9	7.3	5.4	4.1	3.6	2.1	4.5	5.2	6.9	3.1	2.4	5.7	4.4
3.4	8.1	5.7	4.4	4.9	1.5	1.5	2.9	6.3		4.9	8.6	4.3
	7.5	5.3	4.4	2.8	2.3	2.6	2.3	3.6	2.2	1.6	5.2	3.5
2.0	6.0	4.5	2.5	3.3	2.1	2.4	7.1	7.1	2.5	2.7	4.6	3.5
2.2	5.3	3.5	2.9	1.7	3.2	2.3	2.9	3.5	2.2	1.9	3.8	2.9
1.8	4.9	3.3	2.3	2.3	2.7	4.7	1.7	3.1		2.1	3.4	2.8
	9.5	7.5	6.0	1.5	2.0	2.0	2.5	4.0	2.0	3.5	6.0	3.6
<1.0	7.0	4.0	2.0	2.0	<2.0	<2.0	4.5	<3.0	3.0	4.0	5.0	3.6
<2.0	6.0	8.0	<1.0	3.0	6.0	<2.0	<2.0	<3.0	2.0	1.5	5.0	<3.7
6.0	8.0	5.0	<1.0	<1.0	<1.0	1.0	<2.0	<2.0		2.0	15.0	3.8
					<10	<10	129	47		42		54
					<10	<10	135	249		66		83
					<15	10	110	80		40		51
80	160	<5	15	<5	5	5	50	85		235		54
	17	6	3	4	7	6	15	13	3	9	19	9.3
6	15	5	2	4	6	7	22	12	4	18	11	10.1
<1	9	8	8	<1	5	10	23	20	3	10	25	9.3
15	32	<1	4	<1	2	2	11	21		20	33	12.8
	<10	<10	<10	<10	<20	<15	<20	<30	10	<15	<10	<15
<10	<10	<10	<10	<10	<20	<20	<25	<30	<10	<20	<10	<16
<10	<10	<10	<10	<10	<15	<20	<20	<30	<10	<10	<10	<20
50	<10	50	<10	<10	<10	<10	<20	<30		<20	200	<31
	<5	35	10	<5	<10	15	<10	38	16	<10	28	21
<5	<5	25	<5	<5	15	25	36	82	<5	29	35	28
<5	15	15	10	<5	7	25	<10	170	<5	55	110	37
55	80	65	<5	25	70	110	15	65		25	125	62
	<10	<10	<10	<10	<20	<15	<20	<30	27	<15	<10	<16
20	80	160	<10	<10	<20	<20	<25	<30	<10	<20	60	<33
<10	<10	<10	<10	<10	<15	<20	<20	<30	<10	<10	<10	<19
90	<10	150	<10	50	<10	<10	<20	<30		<20	110	<40

"less than" sign (<) precedes an average in table 1 if the uncertainty due to individual sample "less than" values in the average exceeds 20 percent.

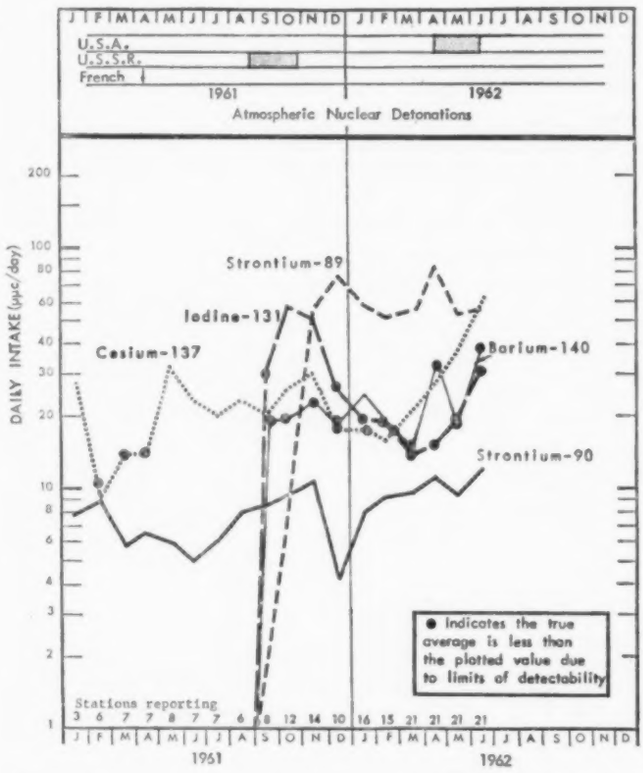

Figure 2.—RADIONUCLIDES IN INSTITUTIONAL DIET SAMPLES—NETWORK AVERAGES

For rapid comprehension, the data are presented graphically in figures 4–10 as station distributions versus daily intake. These are not graphs of continuous functions as might be implied by their appearance. The construction of these graphs is shown in figure 3. In this graph the "total intake" of food is divided into six ranges (< 1.00, 1.00–1.49, 1.50–1.99, 2.00–2.49, 2.50–2.99, and 3.00–3.50 kg/day) and the number of stations in each range is noted and plotted as a bar graph. The maximum of each bar is connected by a smooth curve. This type of construction is used for each month for each item represented in figures 4–10. It should be recognized that there are only 21 stations and that a variation of three stations or 14 percent of the total may not be significant in considering trends in the data.

Discussion of the Data

During the 4-month period reported, the dietary intake of strontium–90 ranged between < 1 and 36 μμc/day with arithmetic average values of 9.3, 10.1, 9.3, and 12.8 μμc/day for the months of March, April, May and June 1962 respectively. These averages lie within the lowest Radiation Protection Guide (RPG) limit of the Federal Radiation Council of 0 to 20 μμc/day for strontium–90 (*2, 3*). The May 1962 *Radiological Health Data* contains a discussion of environmental radiation protection standards which should be referred to for an understanding of the RPG (*3*).

The dietary intake of total radium ranged between < 1.0 and 15.0 μμc/day with 80 percent of the stations reporting less than 6 μμc/day during the entire period. Assuming the radium–226 component of the total radium activity is 30 percent, the intake of radium–226 via the diet probably approaches the Range I level of the RPG (0 to 2 μμc/day for radium–226).

Following the resumption of nuclear weapons testing in the atmosphere in 1961, iodine–131 dietary intake increased from non–detectable to a station high of 228.5 μμc/day (*4*). A peak network average of 56.6 μμc/day occurred in October 1961. During the period of March 1962–June 1962 the station high was 200 μμc/day and the peak network average of < 30.5 μμc/day occurred in June 1962. These averages are in Range II of the iodine–131 RPG (10–100 μμc/day).

The cesium–137 dietary intake network averages have increased from 21.3 μμc/day in March 1962 to 62.1 μμc/day in June 1962. The 1961 network high of 32.6 μμc/day occurred in May. During March, April, and May 1962 most of the stations reported values less than 40 μμc/day. During June 1962, however, the values reported are distributed approximately evenly between 0 and 120 μμc/day (see figure 10).

Comparison of the total dietary intake levels of strontium–90 with those previously reported for milk confirms previous estimates that the milk may account for approximately one–half of the dietary intake of this radionuclide.

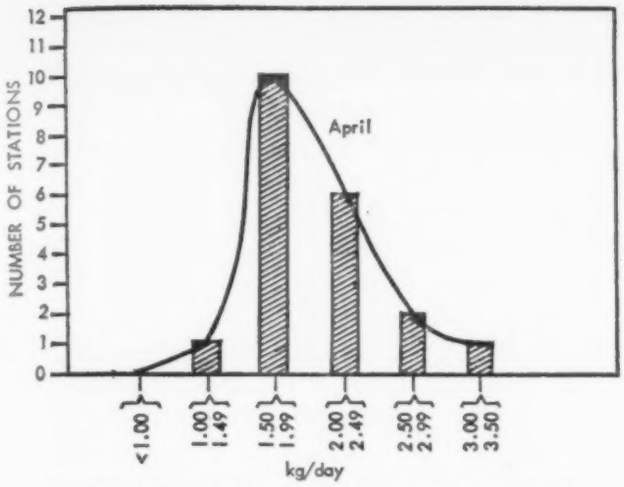

FIGURE 3 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS TOTAL DAILY DIETARY INTAKE ON A WEIGHT BASIS

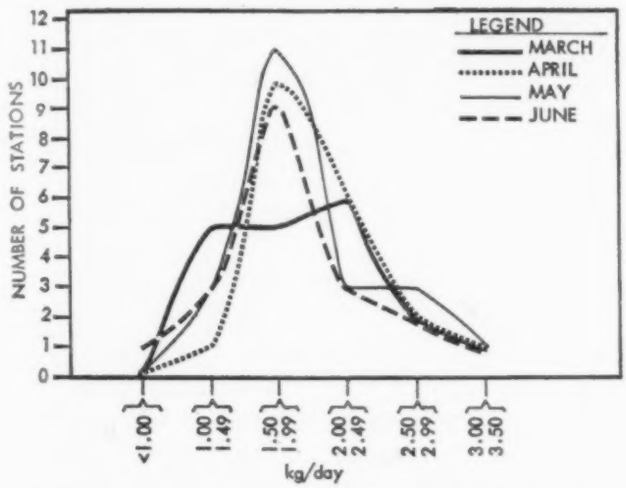

FIGURE 4 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS TOTAL DAILY DIETARY INTAKE ON A WEIGHT BASIS

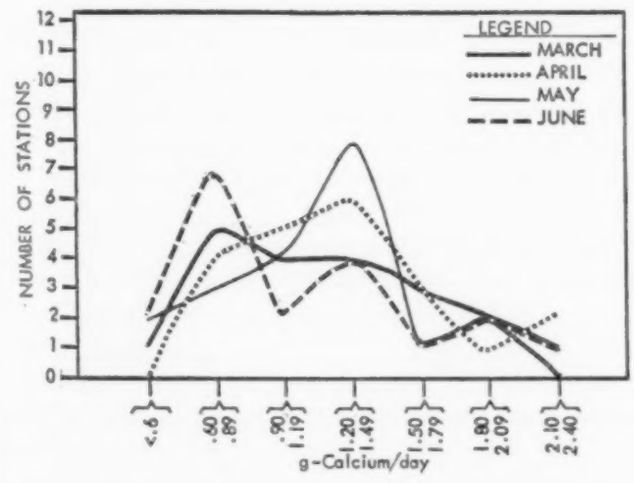

FIGURE 5 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY CALCIUM INTAKE

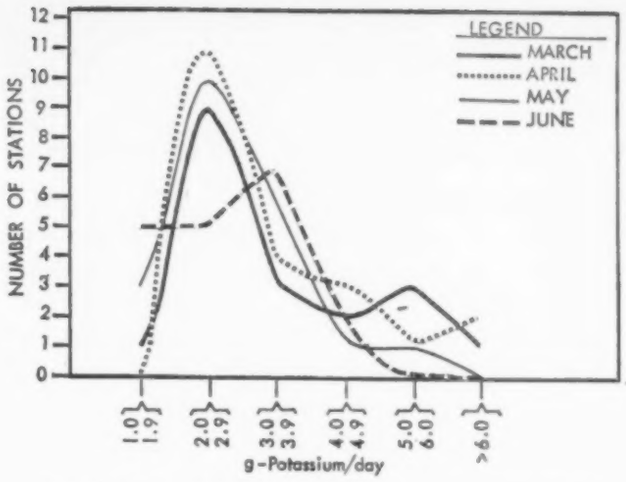

FIGURE 6 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY POTASSIUM INTAKE

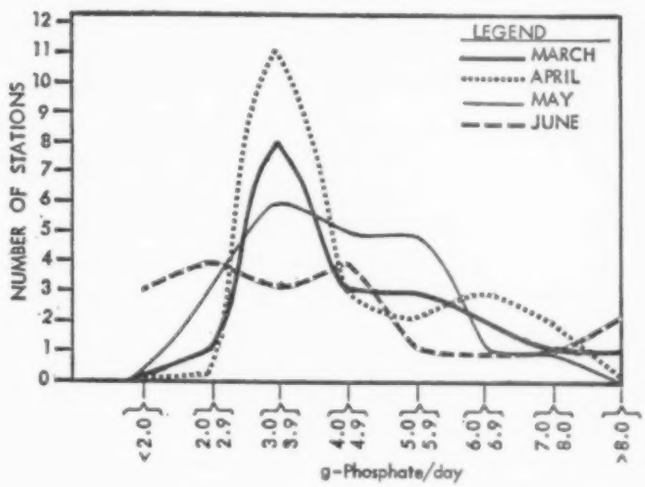

FIGURE 7 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY PHOSPHATE INTAKE

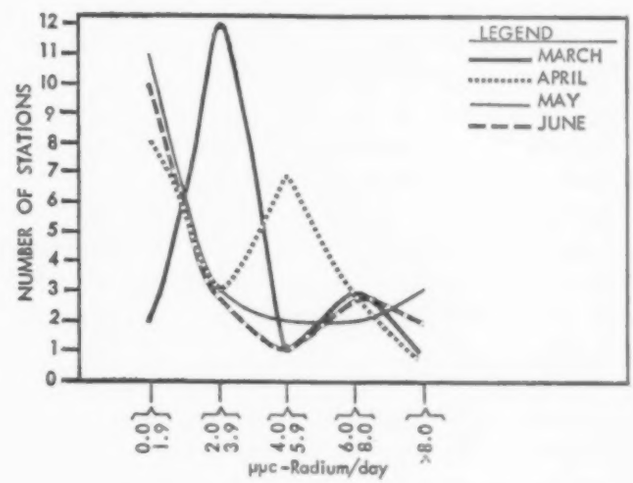

FIGURE 8 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY TOTAL RADIUM INTAKE

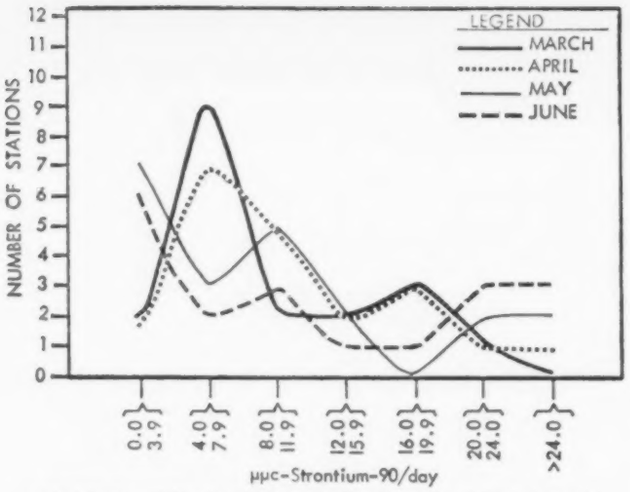

FIGURE 9 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY STRONTIUM-90 INTAKE

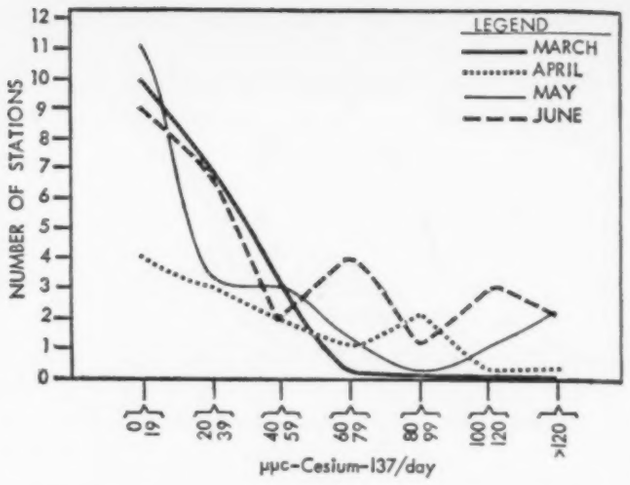

FIGURE 10 -- DISTRIBUTIONS OF INSTITUTIONS VERSUS DAILY CESIUM-137 INTAKE

REFERENCES

(*1*) Anderson, E. C., and D. J. Nelson, Jr.: Surveillance for Radiological Contamination in Foods, *American Journal of Public Health, 52*:1391–400 (September 1962).

(*2*) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2*, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (September 1961), price 20 cents.

(*3*) Chadwick, Donald R. and Conrad P. Straub: Considerations in Establishing Radiation Protection Standards for Radioactivity in the Environment, *Radiological Health Data, III*:159–65 (May 1962).

(*4*) Federal Radiation Council: *Health Implications of Fallout from Nuclear Weapons Testing Through 1961*, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (May 1962), price 15 cents.

Survey of Radioactivity in Food[1]

1960, 1961, and 1962

Division of Pharmacology
Food and Drug Administration

Over the past five years, the Food and Drug Administration (FDA) has conducted an extensive surveillance program on radioactivity in human and animal food, both domestic and imported. This program has been largely directed at assessing the degree of contamination by strontium–90 and cesium–137 in individual foods, and more recently in the total diet. In addition, considerable attention has also been focused on commercial processing of foods in an attempt to learn what effects such operations have on removing radioactive contamination. Finally, since resumption of atmospheric testing, there have been several local fallout situations signalled by the findings of the Radiation Surveillance Network of the Public Health Service. When these have occurred, the Food and Drug Administration, through its field Districts, has sampled vegetation and made analyses for iodine–131.

All the 18 FDA Field Districts are involved in the collection of samples for analysis. There are now 10 Districts (Seattle, San Francisco, Dallas, Denver, Kansas City, Detroit, Atlanta, Minneapolis, Baltimore and Philadelphia) which have the capabilities for making strontium–90 determinations. All Districts are also supplied with portable monitoring equipment sufficiently sensitive to be useful for screening purposes. Ten of the Districts are about to acquire semi-portable scintillometers which will be useful in measuring total gamma activity and also in giving a rough quantitation of iodine–131.

In Washington, the Division of Pharmacology has complete laboratory facilities for

[1] Based on data presented by Dr. Edwin P. Laug, Chief, Radioactivity Branch, FDA, at the International Training Course on Surveys For Radionuclides in Foods, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, October 8, 1962.

measuring strontium–90 and total beta activity. This laboratory also makes cesium–137 and iodine–131 determinations by gamma spectrometry. A system of interlaboratory checks on methodology is also maintained. All analyses for strontium–90 made by the District laboratories are checked, collated, and interpreted at the central laboratory and the results published at frequent intervals. Present capability of the Food and Drug Surveillance system for assaying strontium–90 in foods is about 300 samples per month.

Surveillance for Strontium–90 in Individual Foods

Program: Samples are not collected according to a regular schedule or fixed geographical grid. The major growing areas for all products are covered at intervals, usually coinciding with harvest dates for the specific crop. Decisions as to what products to sample, how often, and under what priority are reviewed at intervals and incorporated into the surveillance program. A revised program is issued about once a year. In 1960, 1500 individual food samples were collected and analyzed; last year and again this year, the number was increased to 3500 per year.

Kinds of Products: A preponderance of foods collected are raw agricultural products, but animal fodders and forage are also included. There are roughly 50 different categories. The raw food samples are usually unwashed, unpeeled, and in the condition in which they would be found in a warehouse or store. Most imports are raw and unprocessed also (tea bales, coffee beans, and cocoa beans). As processed samples are collected, an attempt is made to identify the raw lot from which the finished product is manufactured.

Collection Methods: All samples are collected by FDA inspectors, either directly from the individual grower or from the storage sheds where crops are assembled before shipment. Import samples are usually collected at dockside. Collection records kept by the inspector include date of collection, date of harvest, date of planting, name of grower or growers, location of farm by county and State (or foreign country), and name and location of marketing cooperative or dealer. As manufactured items are collected, information on the source of the raw materials is also included.

Surveillance for Cesium–137 in Individual Foods and Total Diet

About 10 percent of all samples collected for strontium–90 analyses are also examined for cesium–137. The latter analyses are made at the Washington laboratory on a 400–channel gamma spectrometer.

Surveillance for Iodine–131

As in the case of strontium–90, samples are not collected according to a fixed schedule. A formal sampling program has not been developed. Iodine–131 surveillance activities are geared to local fallout occurrences for which the alert usually comes from the Public Health Service Radiation Surveillance Network. So far, FDA has participated on two occasions, Fall 1961 and July 1962. At both times there were elevated iodine–131 values in milk, and interest focused on measurements of iodine–131 in grasses and leafy vegetables. Because of the short half–life of iodine–131, it is necessary to have facilities for measurement systematically dispersed throughout the country. At present only the Washington laboratory of FDA can make iodine–131 analyses. When facilities become available at the districts, FDA may be able to develop a formal program.

METHODOLOGY

Strontium–90: The method currently used in the FDA laboratories for the analysis of strontium–90 is essentially that outlined in the HASL Manual of Standard Procedures NYO–4700 (*1*). The method involves reduction of the unwashed and unpeeled food to an ash at 550 to 600° C, solution of the ash in hydrochloric acid, isolation of strontium and calcium as oxalates, and separation of strontium from calcium in concentrated nitric acid. After scavenging operations with barium chromate and yttrium hydroxides to remove radium and lanthanides, respectively, strontium–90 is determined either by isolation and measurement of the daughter product yttrium–90 at secular equilibrium, or by direct measurement of strontium–90 with correction for ingrowth of

daughter product yttrium–90. The second procedure has an advantage in that it obviates the three–week delay period necessary for ingrowth of yttrium–90. Since this method does not differentiate between the different isotopes of strontium present during and after atmospheric tests of nuclear weapons (about 5 percent strontium–89 remains after 8 months), this method is not currently applicable. At present, the first method is being used.

Cesium–137 and Iodine–131: All analyses for these nuclides are made on a 400–channel gamma spectrometer. No chemical processing is required, as the samples are finely chopped or comminuted raw and placed in a plastic 3.7–liter Marinelli beaker that fits over a 3 x 3–inch cylindrical sodium iodide crystal. Determinations are made by integrating the counts under the characteristic peak of each nuclide (I^{131}–0.36 Mev; Cs^{137}–0.66 Mev) with allowances for background and the influence of adjacent peaks.

RESULTS

Strontium–90 in Individual Foods: The results presented are for foods harvested and collected in 1960, 1961, and 1962. They have been arranged without identifying time or source of harvest in order to demonstrate differences between varieties and categories only. Time and location parameters will be discussed later.

Table 1 lists the categories of food in descending order of strontium–90 content, and table 2 lists the strontium–90 content of foods by categories and varieties. The following categories were selected: vegetables, root vegetables, fruits, grains, dairy products, sea foods, nuts, beverage products, and spices. A total of 97 varieties are represented by 2,450 individual samples.

Statistical evaluations of these data have not been attempted. However, inspection shows that some of the differences in strontium–90 between products must be highly significant. In other cases it is sufficient merely to call attention to trends, which may later be more precisely defined with a larger sampling.

Vegetables: Generally, the leafy type carry the largest burden of strontium–90; most notable are parsley, collards, and kale. Of the legumes, soybeans and snap beans contain more strontium–90 than lima beans and peas. The difference in strontium–90 content between cauliflower and broccoli among the brassicae is difficult to explain considering the similarity of growth habit.

Root vegetables: Most striking is the difference in strontium–90 content between white potatoes and sweet potatoes. The former have the lowest concentration of strontium–90 in this category.

Fruits: With the exception of the berries, fruits carry, on the average, one–tenth as much strontium–90 as the vegetables. Notably low are tomatoes, apples, pears,

TABLE 1.—STRONTIUM–90 CONTENT OF FOODS 1960, 1961, 1962

Category	Number varieties	Number samples	Average (pc/kg)	Range (pc/kg)
Tea leaves	1	137	387	19 –1630
Spices	10	51	196	1.9–2590
Dairy products	2	81	41	2.1– 416
Vegetables	22	628	22	0.0– 299
Nuts, shelled	6	82	22	0.0– 119
Grains	6	294	17	0.0– 166
Coffee beans	1	94	17	1.8– 48
Cocoa beans	1	31	14	7.3– 25
Root vegetables	7	352	6.6	0.0– 104
Fruits	24	412	5.0	0.0– 110
Eggs	1	19	1.9	0.4– 35
Sea foods	9	161	1.0	0.0– 9.8

and peaches, and notably high are blueberries, cranberries, and strawberries.

Grains: Outstandingly low levels of strontium–90 in corn and rice were observed.

Dairy products: The findings on cheese and processed milk continue to confirm what has been demonstrated in fresh milk. High levels of strontium–90 in cheese would be expected since this is a "concentration" product from milk. Egg substance contains very little strontium–90 but egg shell contains over 100 times as much. This has been tabulated earlier (*2*). Egg shells are of interest, since they are occasionally processed as a source of calcium.

Sea Foods: Sea foods are generally the lowest source of strontium–90 of all products examined.

Nuts: Outstandingly high in strontium–90 content are brazil nuts and peanuts. Other evidence has shown that brazil nuts concentrate radium from the soil. They appear to take up strontium–90 from the soil in a similar manner, although translocation from leaves cannot be ruled out.

Beverage products: The comparatively high value for tea has been confirmed many times. It may be assumed that a large proportion of the strontium–90 comes from surface contamination. On the other hand, coffee, cocoa beans and nuts, all being protected from surface contamination, must receive the strontium–90 by translocation.

Spices: The extremely high values shown for some of the spices are striking. However, because of the very small contribution of such products to the total diet, the results are merely academic.

TABLE 2.—STRONTIUM–90 CONTENT OF FOODS, 1960–1962

Variety	Number samples	Average (pc/kg)	Range (pc/kg)
Vegetables			
Artichokes	3	6.5	4.0– 8.1
Asparagus	16	3.3	0.3– 12
Beans, lima	25	6.0	0.4– 27
Beans, snap	80	16	1.0– 98
Broccoli	13	20	0.2– 64
Brussel sprouts	5	5.8	0.2– 8.1
Cabbage	101	12	0.7– 51
Cauliflower	15	4.6	0.6– 10
Celery	78	10	0.8– 60
Collards	13	117	29 – 299
Eggplant	2	5.4	4.3– 6.5
Kale	3	132	22 – 237
Lettuce	114	17	0.3– 214
Parsley	25	87	21 – 178
Peas	34	5.4	0.0– 20
Soybeans	47	45	10 – 151
Spinach	56	29	2.7– 167
Root vegetables (washed, unpeeled)			
Beets	24	17	0.7– 104
Carrots	88	6.0	0.5– 28
Onions	60	4.8	0.5– 26
Potatoes, white	116	2.1	0.0– 11
Potatoes, sweet	20	19	4.4– 44
Radishes	19	10	1.1– 51
Turnips	25	12	0.5– 65
Fruits			
Apples	60	1.0	0.0– 2.8
Avocado	6	1.4	0.1– 4.7
Banana	7	0.2	0.1– 0.5
Blueberries	9	10	5.7– 24
Cantaloupes	4	1.4	0.5– 3.4
Cherries	19	6.6	3.4– 9.8
Cranberries	9	37	3.6– 110
Cucumbers	10	3.3	0.8– 8.3
Dates	6	3.4	0.6– 8.7
Figs	14	7.5	2.1– 9.5
Grapes	6	5.2	0.9– 7.9
Grapefruit	5	1.4	0.8– 1.7
Lemon	5	1.1	0.5– 1.8
Olives	5	5.1	2.3– 12
Orange	9	2.1	0.8– 4.7
Peaches	33	1.8	0.4– 12
Pears	4	1.2	0.1– 3.2
Peppers	14	2.3	0.0– 11
Pumpkin	17	7.3	0.5– 26
Raisins	8	3.5	0.0– 8.8
Squash	31	6.7	0.9– 23
Strawberries	46	13	0.9– 37
Tomatoes	83	1.5	0.1– 9.9
Grain			
Barley	36	16	0.5– 69
Corn	48	1.5	0.0– 8.8
Oats	30	31	4.8– 166
Rice	11	3.7	0.2– 8.3
Rye	19	25	6.5– 112
Wheat	150	19	0.9– 108
Dairy Products			
Egg substance	19	1.9	0.4– 3.5
Cheese	55	52	11 – 416
Milk, evaporated	26	16	2.1– 64
Sea Food			
Clams	13	0.9	0.0– 4.6
Crabmeat	4	5.1	4.2– 5.8
Haddock	8	0.5	0.1– 2.1
Lobster	9	0.5	0.0– 1.5
Oysters	23	1.1	0.0– 9.8
Salmon	6	0.6	0.0– 1.4
Sardines	36	1.8	0.0– 8.1
Shrimp	20	0.9	0.0– 3.3
Tuna fish	42	0.3	0.0– 1.7
Beverage products			
Cocoa beans	31	14	7.3– 25
Coffee	94	17	1.8– 48
Tea	137	387	19 –1630
Nuts			
Almonds	8	7.6	0.7– 19
Brazil nuts	9	63	18 – 119
Cashews	15	1.7	0.0– 4.0
Peanuts	22	37	6.8– 81
Pecans	19	15	3.2– 50
Walnuts	9	2.7	0.0– 9.3
Spices			
Caraway seed	6	109	62 – 206
Cardamom	2	161	98 – 223
Cassia	11	260	4.9–2590
Chili peppers	10	22	1.9– 88
Cinnamon	3	1176	531 –1676
Ginger	1	94	
Hops	3	53	50 – 56
Mustard seed	13	50	17 – 96
Sage leaves	1	618	
Thyme leaves	1	885	

TABLE 3.—GEOGRAPHICAL AND TEMPORAL DISTRIBUTION OF STRONTIUM-90

[pc/kg]

Food	Pre-testing averages[a]			Post-testing averages[a]		
	West	Central	East	West	Central	East
Apples	[b]0.5 (8)		1.0 (10)	0.5 (11)		1.2 (15)
Beans, snap	5.1 (11)	28 (19)	24 (20)			
Carrots	2.7 (14)		4.8 (8)			
Lettuce	2.2 (17)			21 (19)		
Tomatoes	0.9 (9)		2.3 (7)	0.9 (7)		3.1 (6)
Wheat	7.8 (10)	18 (12)	28 (13)	10 (10)	18 (8)	28 (4)

[a] Samples harvested before September 15, 1961, are designated as pre-test, and those harvested after September 15, 1961 are designated as post-test.

[b] Numbers in parentheses refer to number of samples.

Geographical and Temporal Distributions of Strontium–90: In table 3, evidence is presented to show the relation of geographical location and the resumption of nuclear tests to the strontium–90 content of foods.

Apples: A trend toward higher values in the east is evident. However, the influence of weapons testing cannot be demonstrated in either eastern or western samples.

Beans, snap: There is a clear indication that the far western growing areas produced snap beans that had significantly lower concentrations of strontium–90 than those produced in central and eastern sections, at least before resumption of nuclear weapons testing in September 1961.

Carrots: A trend towards higher values in eastern samples is indicated.

Lettuce: Influence of U.S.S.R. testing seems demonstrated in lettuce harvested after September 15, 1961.

Tomatoes: Findings on this fruit essentially confirm those made on apples.

Wheat: While there is no clear–cut evidence of debris from recent nuclear weapons testing, the difference between west, central and eastern wheat is striking.

Cesium–137 in Individual Foods: Surveillance of foods for cesium–137 has been limited to about 10 percent of samples assayed for strontium–90. Table 4 shows a representative set of data from individual samples by which the concentrations of cesium–137 and strontium–90 can be compared. On the average there is more cesium–137 in the samples than strontium–90; this has been reported earlier (*3*).

TABLE 4.—CESIUM–137 AND STRONTIUM–90 IN SELECTED INDIVIDUAL RAW FOODS

Item	Cesium–137 (pc/kg)	Strontium–90 (pc/kg)	Cs^{137}/Sr^{90}
Beans, snap	4.5	22	0.2
Cabbage	56	12	4.7
Egg:			
substance	1.7	1.1	1.5
shell	140	390	0.4
Peaches	<2	1.2	<1.7
Potatoes	<6	3	<2
Soybean flour	336	25	13.4
Spinach			
fresh	68	32	2.1
frozen	29	15	1.9
Tomatoes	33	2.6	12.7
Wheat	58	28	2.1

Iodine–131: The Public Health Service Radiation Surveillance Network recorded peaks of total beta particulates in air in the Salt Lake City area on July 8 and 16, 1962. Alerted by these findings, the FDA, through its inspection staff, collected 4 series of leaf lettuce and endive samples from farms in the area on July 13, 18, 27, and August 6. Whenever possible, the consecutive samples all came from the same farm.*

Analyses were made for iodine–131 and total gamma with the 400–channel gamma spectrometer in the Washington laboratories, while total beta and strontium–90 analyses were made at the Denver District laboratories.

**Editors note: For a detailed discussion, see the article entitled, "Iodine–131 in Milk and Vegetables Associated with July 1962 Fallout in Utah," in Section V of this issue.*

SUMMARY

With respect to the quantities of strontium–90 discovered in these surveys the following orientation ranges can be stated: quantities of strontium–90 of the order of 1 picocurie or less per kilogram are merely of academic interest and indicate the "absence" of strontium–90 within the usually accepted standards for sensitivity and accuracy of strontium–90 methods. Quantities of strontium–90 ranging from 1 to 5 pc/kg are considered "low" and of little consequence. In fact, it can be said that food products carrying such amounts should not be considered "active" vectors that receive appreciable transfer of this isotope either through the soil or from fallout in the air. Quantities of strontium–90 ranging from 5 to 20 pc/kg indicate "active" contamination from soil or air. Such levels are hardly likely to contribute significantly to the total daily intake of this isotope. Quantities of the order of 20 to 100 pc/kg of strontium–90 are potentially significant contributors to the total daily intake, i.e., conceivably as much as 50 percent, depending on the average amount of the food eaten. Quantities of the order of 100 pc/kg of strontium–90 or over deserve constant surveillance and are in fact the criteria that could signal various types of corrective action.

Previous coverage in *Radiological Realth Data*:

Period	Issue
1958 and 1959	*May 1960*
1958, 1959, and 1960	*January 1961*
1960	*August 1961*
1959 and 1960	*September 1961*
1958, 1959, 1960, and 1961	*December 1961*
1960 and 1961	*April 1962*
1961	*June 1962*
1960, 1961, and 1962	*August 1962*
1960, 1961, and 1962	*September 1962*

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(*1*) U.S. Atomic Energy Commission: *HASL Manual of Standard Procedures, NYO–4700,* Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. (February 1960), price $1.75.

(*2*) Food and Drug Administration: Strontium–90 in Raw and Processed Foods, *Radiological Health Data 3*:320–33 (September 1962).

(*3*) Food and Drug Administration: Survey of Radioactivity in Food, *Radiological Health Data, 2*:515–8 (December 1961).

SECTION III.—MILK

Radionuclide Analyses of Pasteurized Milk

PASTEURIZED MILK NETWORK
August 1962

Division of Radiological Health
Division of Environmental Engineering and Food Protection
Public Health Service

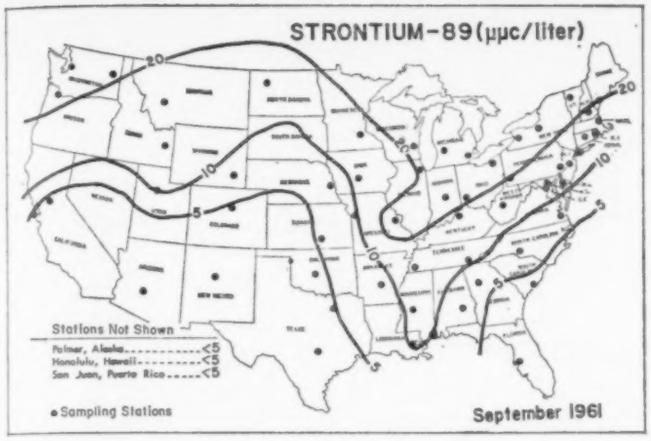
In recognition of the importance of milk as a dietary component, the Public Health Service conducts a continuous monitoring program for radionuclides in pasteurized milk. Milk lends itself readily to a national sampling program because of its widespread and continuous availability and its ease of preparation and analysis compared to other foods.

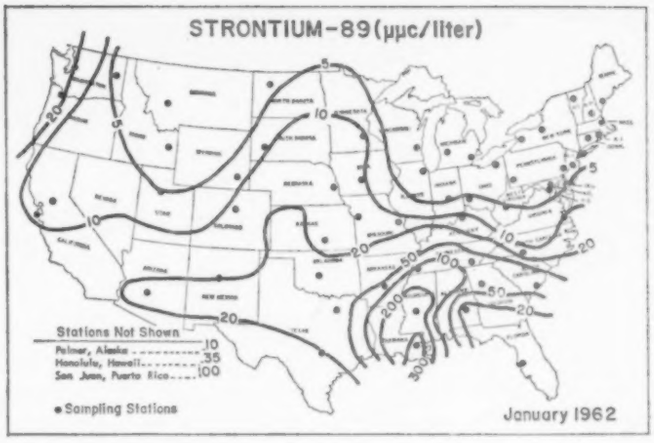
In 1957 the PHS initiated the investigation of raw milk to determine relationships between dairy practices and radionuclide levels in milk. However, it became evident that the milk actually consumed by the population should be included in a broader sampling program. In 1960, the pasteurized milk network was initiated to provide data representative of the milk consumed in selected municipalities. Both raw and pasteurized milk sampling data were reported concurrently until June 1961 to permit comparison of the differences between the earlier, limited, milkshed sampling results and those exhibited in pasteurized milk monitoring. Since June 1961, raw milk sampling has been carried out for investigative rather than monitoring purposes.

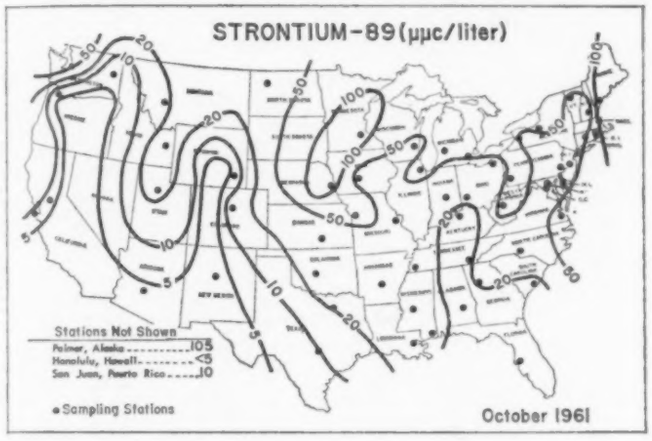
During August 1962, pasteurized milk surveillance was conducted at 62 Pasteurized Milk Network stations with the cooperation of State and local milk sanitation agencies who have been shipping samples to the PHS Southwestern, Southeastern, and Northeastern Radiological Health Laboratories for analysis. Publication in *RHD* follows 3 to 4 months after sample collection because of the time required for shipment, processing, radioanalysis of strontium, data compilation, and publication procedures.

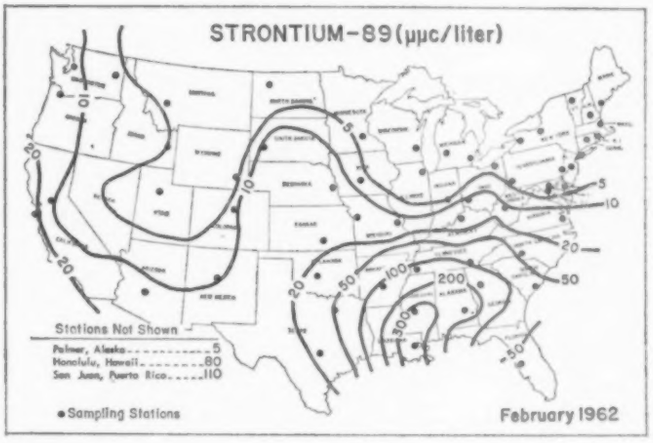
Sampling and Compositing Procedures

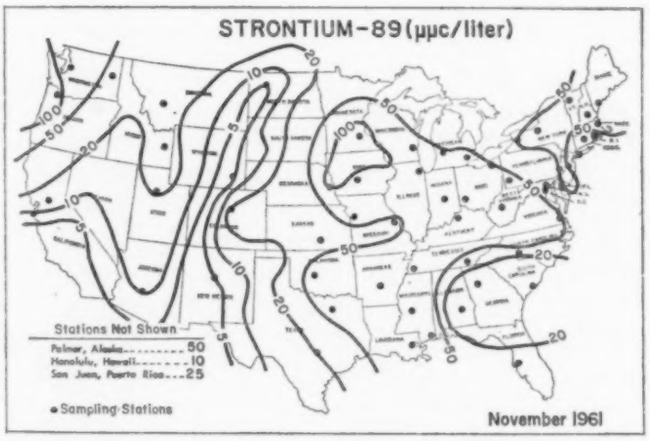
The current program emphasizes (1) measurement of the concentrations of radioactivity in samples of pasteurized milk consumed by the public in various regions of the country, and (2) provision of at least one sampling point within virtually all States and additional points when indicated by widely varying conditions of the milk supply or when needed in order to cover large population groups. Each sample is composited from subsamples collected from each plant in proportion to the relative volumes

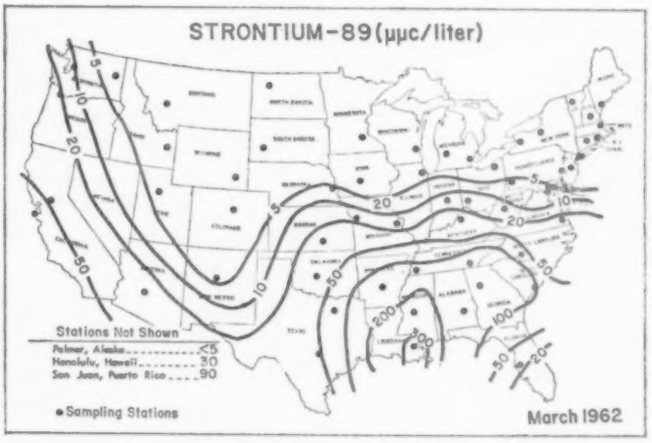


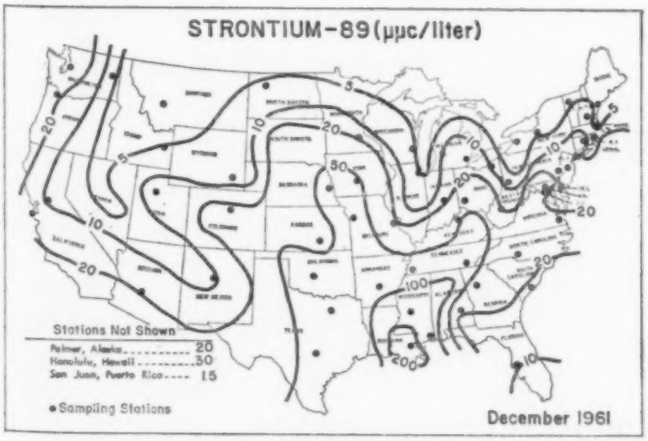












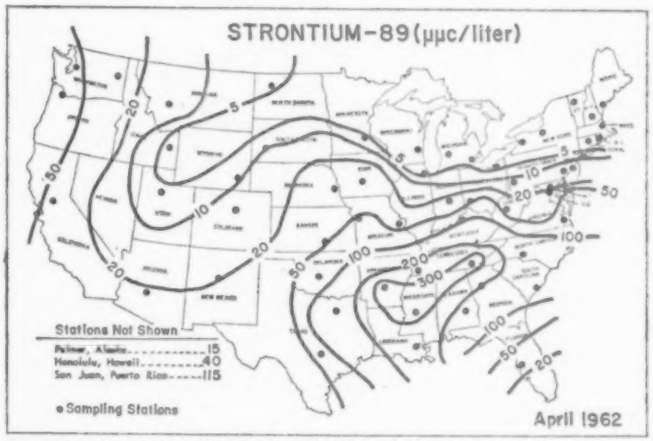


Figure 1.—PASTEURIZED MILK STRONTIUM-89 CONCENTRATION CONTOURS

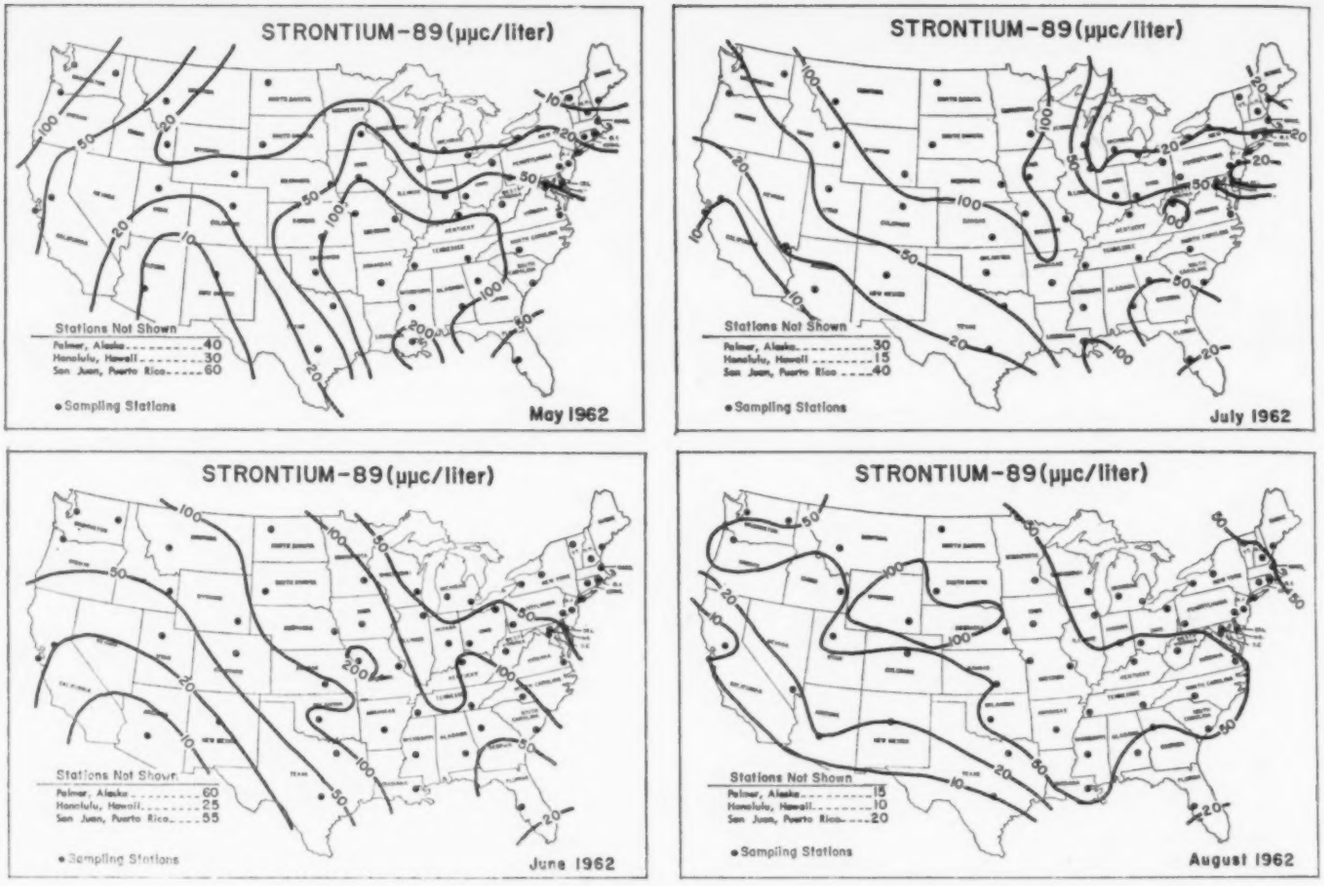


Figure 1.—PASTEURIZED MILK STRONTIUM–89 CONCENTRATION CONTOURS—Continued

of milk sold. While not confirmed for all stations, the objective of this sampling program is to reflect at least 90 percent of each city's milk supply. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of a community's total supply as could be achieved under practical conditions. Since the resumption of nuclear weapons testing, the sampling schedule has been increased in frequency. During August 1962, most stations were sampled twice a week. All surveillance data are subject to continuing review and evaluation to observe unusual patterns or concentrations which may require immediate attention. Further atmospheric nuclear testing may require re–evaluation and adjustment of the sampling frequency and analytical schedule for this program.

Iodine–131, cesium–137, and barium–140 are determined by gamma scintillation spectroscopy,[1] while strontium–89 and strontium–90 are determined following radiochemical separation. The minimum detectable concentrations in units of μμc/liter are: Sr^{89}, 5; Sr^{90}, 1; I^{131}, 10; Cs^{137}, 5; and Ba^{140}, 10.

Table 1 presents summaries of all available analyses for August 1962. When a radionuclide is reported by a laboratory as being below the minimum detectable concentration, one–half of this value is used in calculating the monthly average. A similar procedure is used for the network average.

Geographical Distribution of Radionuclides

Figure 1 geographically displays the monthly average strontium–89 concentrations in pasteurized milk from September 1961 through August 1962. The concentrations generally were below 200 μμc/liter over the entire country from September 1961 through August 1962. However, several sampling stations in the Mississippi Valley at times had concentrations greater than 200 μμc/liter during the period December 1961 through June 1962.

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

Figure 2 shows the strontium–90 monthly average concentration contours for pasteurized milk for August 1962. The November 1962 issue of *RHD* contained strontium–90 contour maps for September 1961 through July 1962. These maps show that from September through December 1961 all stations reported below 20 μμc/liter of strontium–90. From January through March 1962 concentrations of strontium–90 in milk rose to over 20 μμc/liter in the Arkansas–Louisiana–Mississippi area. Concentrations greater than 30 μμc/liter were observed in this same area from April through July 1962. During June 1962, North Dakota and South Dakota also showed concentrations greater than 30 μμc/liter. The concentrations for July 1962 in this region were somewhat lower (approximately 20 μμc/liter) however. The lower Mississippi Valley region as well as several South Atlantic States had strontium–90 concentrations slightly in excess of 20 μμc/liter for the month of August.

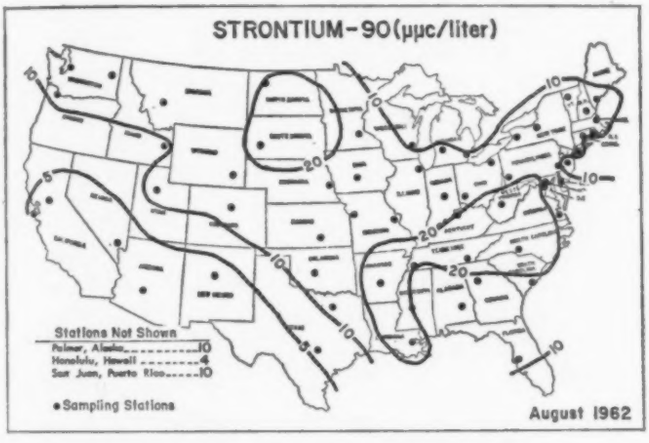


Figure 2.—PASTEURIZED MILK STRONTIUM–90 CONCENTRATION CONTOUR

Figure 3 displays average iodine–131 milk concentration contours for August 1962. The October 1962 issue of *RHD* presents iodine–131 contour maps for the period September 1961 through June 1962. Prior to September 1961 the concentrations of iodine–131 in milk were generally non–detectable (< 10 μμc/liter). From September through November 1961 concentrations greater than 200 μμc/liter appeared at several stations in States bordering the Mississippi River. The levels declined in December 1961. From January through April 1962, iodine–131 concentrations in milk were generally below 20 μμc/liter. Concentrations greater than 200 μμc/liter were seen in various areas in the succeeding months. Concentrations of at least 200 μμc/liter were observed in Kansas and Missouri in May and June 1962. Also, in June 1962, a high of 350 μμc/liter appeared in Spokane, Washington. The greatest July 1962 average (580 μμc/liter) occurred at Salt Lake City, Utah. Concentrations greater than 200 μμc/liter occurred in the Wyoming–Utah area in August 1962.

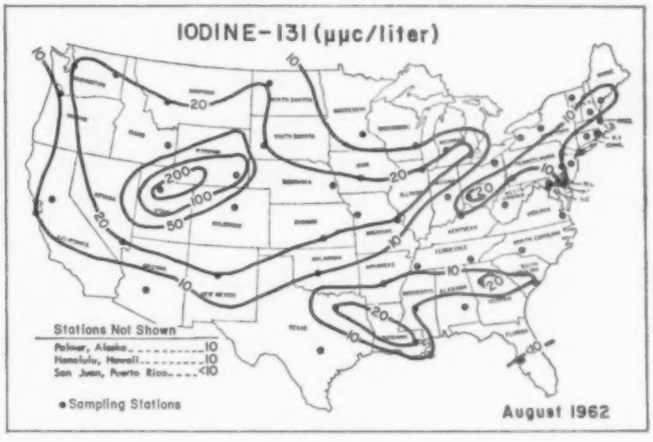


Figure 3.—PASTEURIZED MILK IODINE–131 CONCENTRATION CONTOUR

Selected Monthly Strontium Profiles

In previous issues of *RHD*, the monthly average strontium–90 concentrations in pasteurized milk from selected cities in the monitoring program were published. Profiles for an additional 16 cities are presented in figure 4. These graphs show the strontium–90 concentrations in milk from selected cities in the United States Department of Agriculture marketing regions of the United States.

TABLE 1.—RADIOACTIVITY IN PASTEURIZED MILK, AUGUST 1962

[Average radioactivity concentrations in $\mu\mu c$/liter]

Sampling locations		Calcium (g/liter)		Strontium–89		Strontium–90		Iodine–131		Cesium–137		Barium–140		Last Sr^{90} profile in RHD
		Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	
Ala:	Montgomery	1.20	1.22	105	40	19	12	10	<10	55	35	20	<10	Oct. 62
Alaska:	Palmer	1.08	1.05	35	15	9	10	10	10	20	40	<10	<10	Nov. 62
Ariz:	Phoenix	1.09	1.06	15	20	3	2	<10	<10	10	20	<10	<10	Sep. 62
Ark:	Little Rock	1.17	1.21	225	85	37	27	20	10	95	50	40	20	Nov. 62
Calif:	Sacramento	1.09	1.06	30	5	5	2	10	20	15	25	<10	20	Dec. 62
	San Francisco	1.11	1.09	55	10	9	4	<10	<10	15	20	10	<10	Oct. 62
Colo:	Denver	1.16	1.10	30	40	8	14	<10	30	10	80	<10	<10	Dec. 62
Conn:	Hartford	1.19	1.02	15	30	11	10	<10	<10	35	80	<10	<10	Dec. 62
Del:	Wilmington	1.20	1.06	50	45	15	12	10	10	50	85	<10	<10	Sep. 62
D. C:	Washington	1.15	1.14	50	45	15	16	<10	<10	40	65	10	<10	Oct. 62
Fla:	Tampa	1.21	1.22	25	25	10	11	<10	<10	105	150	<10	<10	Sep. 62
Ga:	Atlanta	1.20	1.21	120	50	22	18	<10	20	80	55	20	<10	Oct. 62
Hawaii:	Honolulu	1.08	1.05	30	10	5	4	<10	10	25	40	<10	<10	Nov. 62
Idaho:	Idaho Falls	1.09	1.04	25	40	7	9	10	30	20	70	10	10	Sep. 62
Ill:	Chicago	1.16	1.10	35	40	11	14	20	20	30	65	10	<10	Oct. 62
Ind:	Indianapolis	1.20	1.12	50	50	15	12	20	<10	40	45	20	<10	Dec. 62
Iowa:	Des Moines	1.08	1.08	95	75	15	15	60	20	25	45	20	20	Sep. 62
Kans:	Wichita	1.08	1.07	65	50	12	13	120	20	20	40	20	<10	Nov. 62
Ky:	Louisville	1.17	1.19	115	80	21	20	20	10	40	35	20	10	Sep. 62
La:	New Orleans	1.23	1.22	215	75	37	27	<10	20	135	75	30	20	Nov. 62
Maine:	Portland	1.22	1.16	20	55	12	14	<10	20	50	130	<10	<10	Sep. 62
Md:	Baltimore	1.17	1.16	45	40	15	20	10	<10	50	70	10	<10	Sep. 62
Mass:	Boston	1.16	1.10	20	50	13	19	<10	10	50	145	<10	<10	Oct. 62
Mich:	Detroit	1.17	1.06	25	30	11	10	<10	20	30	80	<10	<10	Dec. 62
	Grand Rapids	1.23	1.12	20	35	10	11	<10	20	30	65	<10	<10	Sep. 62
Minn:	Minneapolis	1.08	1.06	60	60	13	19	50	<10	30	105	10	<10	Oct. 62
Miss:	Jackson	1.26	1.26	220	80	33	20	<10	10	85	45	30	20	Dec. 62
Mo:	Kansas City	1.09	1.05	130	80	18	14	150	30	30	30	40	10	Dec. 62
	St. Louis	1.08	1.04	85	55	16	16	30	20	30	40	10	10	Nov. 62
Mont:	Helena	1.08	1.11	45	60	10	12	20	20	25	80	10	10	Nov. 62
Nebr:	Omaha	1.13	1.07	65	85	13	12	40	40	20	50	10	20	Sep. 62
Nev:	Las Vegas*		1.04		15		3		20		45		<10	
N. H:	Manchester	1.15	1.16	15	45	10	17	<10	20	60	155	<10	<10	Sep. 62
N. J:	Trenton	1.13	1.11	25	35	10	9	<10	<10	30	70	<10	<10	Dec. 62
N. Mex:	Albuquerque	1.09	1.07	15	20	4	3	10	20	<5	25	10	<10	Nov. 62
N. Y:	Buffalo	1.16	1.11	20	30	10	16	<10	<10	40	80	<10	<10	Dec. 62
	New York	1.13	1.03	20	40	12	14	10	<10	40	95	<10	<10	Oct. 62
	Syracuse	1.17	1.12	20	40	10	13	20	<10	25	70	<10	<10	Nov. 62
N. C:	Charlotte	1.22	1.21	95	55	22	23	<10	<10	55	50	20	10	Nov. 62
N. Dak:	Minot	1.10	1.11	60	70	16	21	20	20	30	75	<10	10	Sep. 62
Ohio:	Cincinnati	1.18	1.12	65	55	17	14	20	20	30	40	20	<10	Dec. 62
	Cleveland	1.15	1.12	35	30	11	12	<10	<10	30	55	<10	<10	Nov. 62
Okla:	Oklahoma City	1.15	1.15	115	60	21	14	60	10	60	30	30	10	Oct. 62
Ore:	Portland	1.13	1.08	95	130	17	12	10	10	55	70	10	<10	Dec. 62
Pa:	Philadelphia	1.16	1.14	35	40	13	10	<10	10	45	75	<10	<10	Nov. 62
	Pittsburgh	1.17	1.14	35	45	14	19	10	10	45	90	<10	<10	Nov. 62
P. R:	San Juan	1.13	1.18	75	20	11	10	20	<10	55	40	20	<10	Nov. 62
R. I:	Providence	1.19	1.11	20	40	12	13	10	<10	45	95	<10	<10	Sep. 62
S. C:	Charleston	1.20	1.20	95	55	21	19	<10	10	75	60	20	<10	Dec. 62
S. Dak:	Rapid City	1.09	1.07	70	90	17	27	<10	20	30	90	10	10	Oct. 62
Tenn:	Chattanooga	1.24	1.24	200	75	28	24	10	<10	90	50	30	10	Oct. 62
	Memphis	1.21	1.22	160	50	27	20	<10	<10	40	25	30	<10	Sep. 62
Tex:	Austin	1.17	1.16	35	10	8	6	<10	<10	25	15	<10	<10	Oct. 62
	Dallas	1.18	1.16	115	40	18	11	20	20	50	30	20	<10	Dec. 62
Utah:	Salt Lake City	1.11	1.06	25	80	8	13	<10	330	30	95	<10	30	Nov. 62
Vt:	Burlington	1.13	1.05	15	50	10	13	<10	<10	30	125	<10	<10	Dec. 62
Va:	Norfolk	1.19	1.19	70	55	17	19	<10	<10	55	70	10	<10	Dec. 62
Wash:	Seattle	1.12	1.08	80	40	18	14	<10	20	55	95	<10	<10	Oct. 62
	Spokane	1.15	1.16	60	35	14	14	120	20	35	75	<10	<10	Dec. 62
W. Va:	Charleston	1.17	1.15	80	85	18	26	20	<10	35	45	20	10	Oct. 62
Wis:	Milwaukee	1.20	1.11	15	25	8	10	10	10	15	65	<10	<10	Sep. 62
Wyo:	Laramie	1.10	1.08	30	150	8	15	20	160	25	100	10	30	Sep. 62
Network average		1.15	1.12	64	50	14.4	14.1	19	20	42	65	12	8	

* The Las Vegas station entered the network in July 1962.

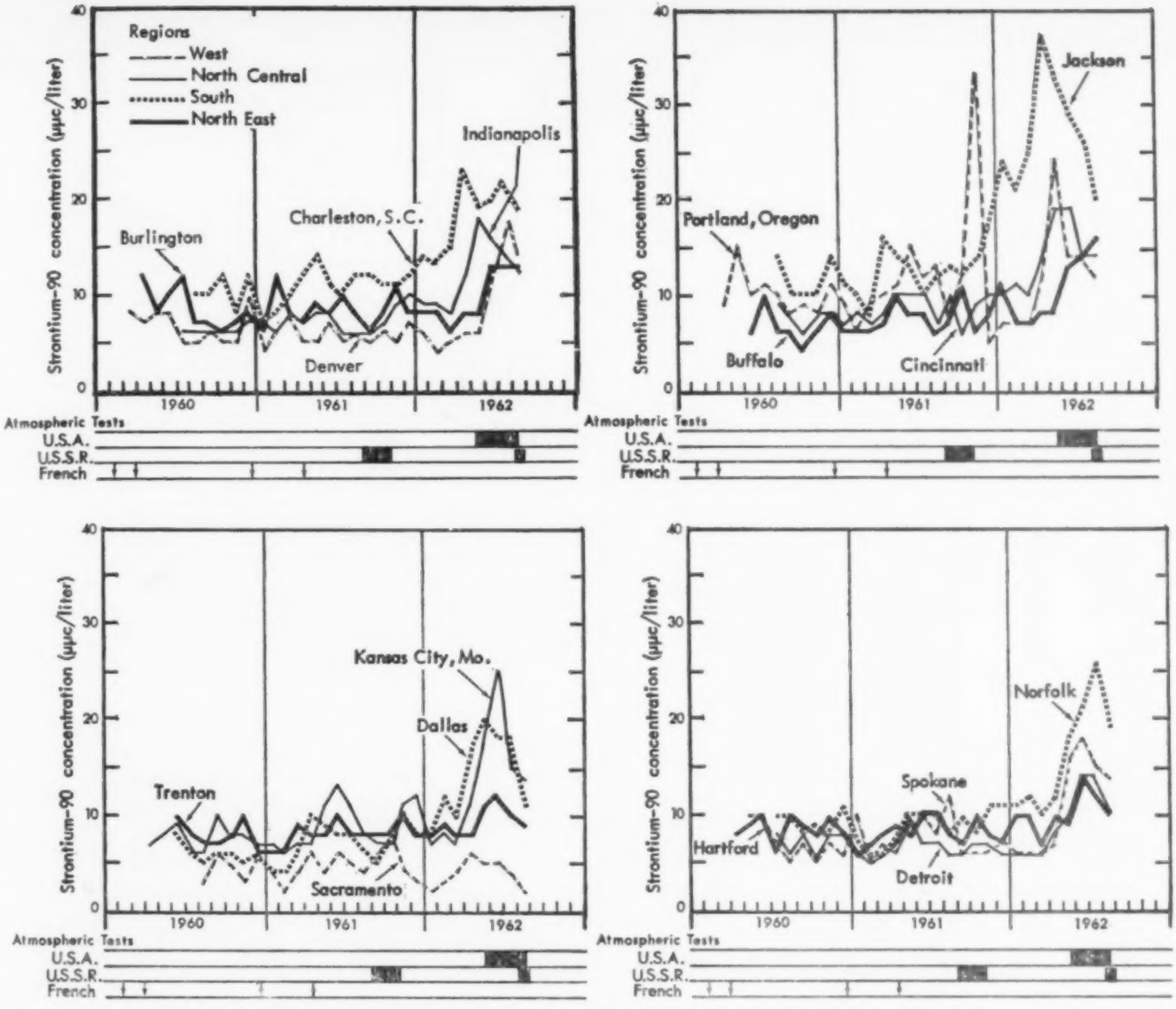


Figure 4.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK

TWELVE-MONTH SUM OF DAILY RADIONUCLIDE CONTENT OF ONE LITER OF PASTEURIZED MILK

October 1961—September 1962: Iodine–131
September 1961—August 1962: Strontium–90

Division of Radiological Health,
Public Health Service

The guidance of the Federal Radiation Council is given in terms of transient rates of intake of radioactive materials in micromicrocuries per day. The ranges are based on radiation doses considered acceptable for lifetime exposure from normal peacetime operations. The Council recommends the use of a time period of one year as an appropriate interval for averaging exposures (*1*, *2*).

To facilitate comparison of the concentration of certain radionuclides in milk with the Radiation Protection Guides, tables 2 and 3 below furnish a means towards estimating the contribution of milk to the total dietary intake of iodine–131 and strontium–90 respectively. The tables are based on the same data which are used for computing the Pasteurized Milk Network monthly averages. They present index values which are the sum of the daily amounts of a radionuclide in one liter of milk for a 12 month period.

The tables show 12-month index values for

TABLE 2.—TWELVE-MONTH SUM OF DAILY AMOUNTS OF IODINE-131 IN ONE LITER OF MILK

Sampling locations		Sep. 1962 iodine-131 averages ($\mu\mu$c/liter)	Iodine-131 index values ($\mu\mu$c day/liter)[a]			
			Sep. 1961—Aug. 1962	Sep. 1961[b]	Aug. 26, 1962—Sep. 29, 1962	Oct. 1961—Sep. 1962
Ala:	Montgomery	20	4,650	900	700	4,450
Alaska:	Palmer	730	24,010	9,900	25,550	39,660
Ariz:	Phoenix	10	8,460	1,800	350	7,010
Ark:	Little Rock	20	14,860	3,600	700	11,960
Calif:	Sacramento	<10	4,760	300	180	4,640
	San Francisco	20	4,590	600	700	4,690
Colo:	Denver	20	9,670	1,800	700	8,570
Conn:	Hartford	70	6,230	1,800	2,450	6,880
Del:	Wilmington	70	7,620	1,800	2,450	8,270
D. C:	Washington	60	5,640	1,200	2,100	6,540
Fla:	Tampa	<10	5,630	1,200	180	4,610
Ga:	Atlanta	10	9,190	2,400	350	7,140
Hawaii:	Honolulu	10	4,440	600	350	4,190
Idaho:	Idaho Falls	40	16,470	4,200	1,400	13,670
Ill:	Chicago	100	14,660	3,300	3,500	14,860
Ind:	Indianapolis	70	9,010	2,100	2,450	9,360
Iowa:	Des Moines	120	32,750	8,700	4,200	28,250
Kans:	Wichita	30	26,740	3,900	1,050	23,890
Ky:	Louisville	40	10,790	2,700	1,400	9,490
La:	New Orleans	<10	9,840	2,700	180	7,320
Maine:	Portland	60	7,310	600	2,100	8,810
Md:	Baltimore	60	7,100	2,100	2,100	7,100
Mass:	Boston	70	10,950	3,900	2,450	9,500
Mich:	Detroit	120	17,850	6,300	4,200	15,750
	Grand Rapids	70	9,660	2,700	2,450	9,410
Minn:	Minneapolis	100	32,060	10,200	3,500	25,360
Miss:	Jackson	<10	12,570	4,500	180	8,250
Mo:	Kansas City	60	33,650	4,500	2,100	31,250
	St. Louis	50	19,060	5,400	1,750	15,410
Mont:	Helena	90	17,950	4,800	3,150	16,300
Nebr:	Omaha	80	27,720	7,500	2,800	23,020
Nev:	Las Vegas[c]	20	2,240	[d]—	700	2,940
N. H:	Manchester	60	9,220	3,000	2,100	8,320
N. J:	Trenton	50	7,890	2,700	1,750	6,940
N. Mex:	Alberquerque	20	7,420	900	700	7,220
N. Y:	Buffalo	100	8,650	3,000	3,500	9,150
	New York	90	10,590	4,200	3,150	9,540
	Syracuse	90	12,160	4,200	3,150	11,110
N. C:	Charlotte	<10	4,570	1,200	180	3,550
N. Dak:	Minot	170	9,990	900	5,950	15,040
Ohio:	Cincinnati	80	12,380	3,000	2,800	12,180
	Cleveland	90	9,270	3,000	3,150	9,420
Okla:	Oklahoma City	20	19,130	2,700	700	17,130
Ore:	Portland	30	11,980	1,800	1,050	11,230
Pa:	Philadelphia	60	8,170	2,400	2,100	7,870
	Pittsburgh	70	9,180	2,700	2,450	8,930
P. R:	San Juan	<10	4,890	600	180	4,470
R. I:	Providence	50	8,330	2,400	1,750	7,680
S. C:	Charleston	10	7,230	2,770	350	4,810
S. Dak:	Rapid City[e]	130	3,400	—	4,550	7,950
Tenn:	Chattanooga	20	8,630	2,400	700	8,930
	Memphis	20	14,910	4,800	700	10,810
Tex:	Austin	<10	5,150	600	180	4,730
	Dallas	<10	8,060	600	180	7,640
Utah:	Salt Lake City	40	37,040	4,200	1,400	34,240
Vt:	Burlington	60	9,100	3,000	2,100	8,200
Va:	Norfolk	20	7,600	2,400	700	5,900
Wash:	Seattle	30	11,280	300	1,050	12,030
	Spokane	60	25,590	3,600	2,100	24,090
W. Va:	Charleston	30	6,700	1,800	1,050	5,950
Wis:	Milwaukee	120	14,410	4,500	4,200	14,110
Wyo:	Laramie	40	20,790	1,200	1,400	20,990

[a] The data in this table are index values, not to be interpreted as consumption or total intake values. Annual I^{131} intake per person may be calculated from an index value in this table by applying the appropriate factor representing average individual daily milk consumption for any selected group under consideration.

Example: 12-month I^{131} index X milk consumption factor = 12-month I^{131} intake.
($\mu\mu$c day/liter) (liter/day/person) ($\mu\mu$c/person)

[b] Index values for stations for which September 1961 data were not available include an estimate for that month based on the October 1961 values.
[c] Station began operation in July 1962; total is for 3 months.
[d] Dash indicates no data available.
[e] Station began operation in January 1962; total is for 9 months.

each of the Network's 62 sampling locations. The first column in each table shows the monthly radionuclide averages. The second column consists of 12-month index values. Due to the longer time required for strontium-90 analysis, the 12-month index values for this radionuclide are for the year beginning one month earlier than the iodine-131 values. The

TABLE 3.—TWELVE-MONTH SUM OF DAILY AMOUNTS OF STRONTIUM-90 IN ONE LITER OF MILK

Sampling locations		Aug 1962 Strontium-90 averages (μμc/liter)	Strontium-90 index values (μμc day/liter)[a]			
			Aug. 1961—July 1962	Aug. 1961	July 29, 1962—Aug. 25, 1962	Sep. 1961—Aug. 1962
Ala:	Montgomery[b]	12	3,751	[c]—	336	4,087
Alaska:	Palmer	10	3,170	217	280	3,233
Ariz:	Phoenix	2	1,360	124	56	1,292
Ark:	Little Rock	27	8,630	496	756	8,890
Calif:	Sacramento	2	1,638	124	56	1,570
	San Francisco	4	1,887	155	112	1,844
Colo:	Denver	14	2,633	186	392	2,839
Conn:	Hartford	10	3,378	248	280	3,410
Del:	Wilmington	12	4,225	372	336	4,189
D. C:	Washington	16	3,706	217	448	3,937
Fla:	Tampa	11	2,678	155	308	2,831
Ga:	Atlanta	18	5,407	310	504	5,601
Hawaii:	Honolulu	4	1,988	186	112	1,914
Idaho:	Idaho Falls	9	2,233	186	252	2,299
Ill:	Chicago	14	2,848	124	392	3,116
Ind:	Indianapolis	12	3,730	186	336	3,880
Iowa:	Des Moines	15	3,779	186	420	4,013
Kans:	Wichita	13	3,613	217	364	3,760
Ky:	Louisville	20	5,088	248	560	5,400
La:	New Orleans	27	9,142	434	756	9,464
Maine:	Portland	14	4,122	310	392	4,204
Md:	Baltimore	20	3,895	310	560	4,145
Mass:	Boston	19	4,171	279	532	4,424
Mich:	Detroit	10	2,905	186	280	2,999
	Grand Rapids	11	2,994	186	308	3,116
Minn:	Minneapolis	19	4,156	341	532	4,347
Miss:	Jackson	20	7,895	372	560	8,083
Mo:	Kansas City	14	4,114	248	392	4,258
	St. Louis	16	4,045	186	448	4,307
Mont:	Helena	12	2,921	124	336	3,133
Nebr:	Omaha	12	3,789	279	336	3,846
Nev:	Las Vegas[d]	3	168	—	84	252
N. H:	Manchester	17	3,980	310	476	4,146
N. J:	Trenton	9	3,264	248	252	3,268
N. Mex:	Alberquerque	3	1,666	155	84	1,595
N. Y:	Buffalo	16	3,198	186	448	3,460
	New York	14	3,635	186	392	3,841
	Syracuse	13	2,843	186	364	3,021
N. C:	Charlotte	23	5,511	403	644	5,752
N. Dak:	Minot[e]	21	4,168	—	588	4,756
Ohio:	Cincinnati	14	4,192	217	392	4,367
	Cleveland	12	3,238	248	336	3,326
Okla:	Oklahoma City	14	4,457	186	392	4,663
Ore:	Portland	12	4,649	403	336	4,582
Pa:	Philadelphia	10	3,588	279	280	3,589
	Pittsburgh	19	4,154	310	532	4,376
P. R:	San Juan	10	2,844	124	280	3,000
R. I:	Providence	13	3,778	403	364	3,739
S. C:	Charleston	19	5,534	372	532	5,694
S. Dak:	Rapid City[f]	27	2,836	—	756	3,592
Tenn:	Chattanooga	24	6,502	372	672	6,802
	Memphis	20	6,280	372	560	6,468
Tex:	Austin	6	2,027	62	168	2,133
	Dallas	11	4,204	186	308	4,326
Utah:	Salt Lake City	13	2,252	124	364	2,492
Vt:	Burlington	13	3,171	248	364	3,287
Va:	Norfolk	19	4,753	248	532	5,037
Wash:	Seattle	14	4,348	248	392	4,492
	Spokane	14	3,369	372	392	3,389
W. Va:	Charleston	26	4,762	310	728	5,180
Wis:	Milwaukee	10	2,427	124	280	2,583
Wyo:	Laramie	15	2,501	155	420	2,766

[a] The data in this table are index values, not to be interpreted as consumption or total intake values. Annual strontium-90 intake per person may be calculated from an index value in this table by applying the appropriate factor representing average individual daily milk consumption for any selected group under consideration.

Example: 12-month Sr^{90} index X milk consumption factor = 12-month Sr^{90} intake.
(μμc day/liter) (liter/day/person) (μμc/person)

[b] The station began operation in October 1961.
[c] Dash indicates no data available.
[d] The station began operation in July 1962.
[e] The station began operation in September 1961.
[f] The station began operation in January 1962.

following two columns in each table are used to compute the net change as the yearly index values are advanced by one month. The last column shows this new 12-month index value.

The data in tables 2 and 3 are calculated as follows: (a) results from all samples collected in each week (Sunday through Saturday) are averaged, (b) the weekly averages for all weeks

ending within a given month are averaged and a daily average for the month is obtained, and (c) the monthly radionuclide index value is determined by multiplying the daily average for the month by the number of days in the month. The number of days in the month will be either 28 or 35, corresponding to the complete calendar weeks used for any month. Procedures exemplified by (a) and (b) above minimize the effect of any one day's sample results on the average for the month.

For a number of reasons it is desirable to have a standard quantity of milk to use in the development of index values for the different radionuclides. In the case of strontium, 1 liter is a suitable quantity as this amount of milk supplies approximately 1 gram of calcium, the amount used by the Federal Radiation Council in deriving the intake guidance for strontium. In the case of iodine–131, the critical age group is the young infant. Available information suggests that the average milk consumption of infants in the 6–18 month group is not more than 1 liter per day. Thus the index value based on 1 liter of milk, though not directly an average intake value, is probably the most useful index for estimating total intake.

REFERENCES

(*1*) Chadwick, Donald R., and Conrad P. Straub: Considerations in Establishing Radiation Protection Standards for Radioactivity in the Environment, *Radiological Health Data, 3*:159–65 (May 1962).

(*2*) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2,* Superintendent of Documents, U.S. Government Printing Office (September 1961), price 20 cents.

INDIANA MILK NETWORK
August 1962–September 1962

Bureau of Environmental Sanitation
Indiana State Board of Health

In September 1961 the Indiana State Board of Health initiated a program of milk sampling for radiological analyses. Indiana was geographically divided into five major milksheds with one large dairy within each milkshed being selected as a sampling station (see figure 5).

Figure 5.—INDIANA MILK SAMPLING LOCATIONS

The milk samples are routinely analyzed for iodine–131, cesium–137, barium–lanthanum–140, strontium–89, and strontium–90. Analyses for iodine–131, cesium–137, and barium–lanthanum–140 are conducted on a weekly basis except when iodine–131 results exceed 100 μμc/liter at which time the frequency of sampling is increased. Samples which are analyzed for strontium–89 and strontium–90 are composited weekly and analyzed monthly.

The trichloroacetic acid analytical procedure (*1*) is used for strontium–89 and strontium–90 analyses. A 512–channel pulse height analyzer and shielded 4″ x 4″ NaI crystal are used for the gamma scintillation analysis of iodine–131, cesium–137, and barium–lanthanum–140.

The monthly averages of the data obtained for the individual sampling stations and the State averages are reported in table 4. The State average is an arithmetic average of the station values. There are no strontium–89 and strontium–90 results for August 1962 due to technical difficulties. Strontium–89 and strontium–90 results for September 1962 will be available next month.

TABLE 4.—INDIANA MILK NETWORK, AUGUST 1962—SEPTEMBER 1962

[Concentrations in μμc/liter]

Sampling locations	Iodine–131		Cesium–137		Barium–140	
	Aug 1962	Sept 1962	Aug 1962	Sept 1962	Aug 1962	Sept 1962
Evansville	20	70	30	20	<10	<10
Fort Wayne	20	150	40	40	<10	10
Indianapolis	<10	90	35	30	<10	10
Rochester	10	130	45	40	<10	10
Seymour	20	60	45	35	<10	10
State average	20	100	40	35	<10	10

REFERENCE

(*1*) Robert A. Taft Sanitary Engineering Center: *Radionuclide Analysis of Environmental Samples, Technical Report R59–6:* SS–E–1 (November 16, 1959).

SECTION IV.—WATER

Radioactivity in Raw Surface Waters

NATIONAL WATER QUALITY NETWORK
June 1962

Division of Water Supply and Pollution Control, Public Health Service

In October 1957 the National Water Quality Network was begun (*1*). This network, operated by the Public Health Service in cooperation with State and local agencies, consisted of 119 stations as of June 30 (see figure 1). These stations are located on the major waterways used for public water supplies, propagation of fish and wildlife, and recreational, agricultural, and industrial purposes. Samples are taken weekly, monthly, or continuously, depending on the type of analysis and the water quality. These samples are analyzed for plankton population, organic chemicals, chemical, biological, and physical quality, and radioactivity (*2*, *3*).

The radioactivity associated with dissolved solids provides a rough measure of the levels which may be found in treated water, since nearly all of the suspended matter is removed by treatment procedures (*4*). It has been observed that in water the natural environmental beta activity is usually several times that of the natural environmental alpha activity. Nuclear installations may contribute additional alpha or beta activity whereas fallout contributes primarily additional beta activity. Gross alpha and beta measurements are made on both suspended and dissolved solids (strontium–90 on the total solids only) in raw surface water samples according to established procedures. (*5*, *6*).

Figure 1.—NATIONAL WATER QUALITY NETWORK SAMPLING STATIONS, JUNE 1962

For the first two years, beta determinations were made on weekly samples, and alpha determinations were generally made on composites of more than one weekly sample. From January 1960 to September 1961, alpha and beta determinations were generally made once a month on weekly composited samples. Beginning in September 1961, alpha determinations have been made on one sample each month, and beta determinations have generally been made on weekly samples. For the first operating year of

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS

[Average concentrations in μμc/liter]

Station	Quarter ending Dec. 31, 1961	June 1962					
	Total Strontium-90	Beta activity			Alpha activity		
		Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River: Pittsburgh, Pa	-	1	17	18	—	—	—
Animas River: Cedar Hill, N. Mex	0.9	10	18	28	2	1	3
Apalachicola River: Chattahoochie, Fla	—	4	12	16	0	0	0
Arkansas River:							
Coolidge, Kansas	.0	201	119	320	42	14	56
Pendleton Ferry, Ark	0.5	—	—	—	—	—	—
Ponca City, Okla	0.6	344	72	416	—	—	—
Big Horn River: Hardin, Mont	—	165	39	204	43	5	48
Big Sioux River: Sioux Falls, So. Dak	1.2	38	104	142	2	3	5
Chattahoochie River:							
Atlanta, Ga	0.3	8	6	14	0	0	0
Columbus, Ga	—	3	7	10	1	0	1
Chena Slough: Fairbanks, Alaska	—	7	10	17	1	0	1
Clear Water River: East Lewiston, Idaho	0.3	2	9	11	0	0	0
Colorado River:							
Loma, Colo	—	15	18	33	2	2	4
Page, Ariz	—	56	14	70	12	3	15
Boulder City, Nev	1.8	0	20	20	0	6	6
Yuma, Ariz	—	13	52	65	—	—	—
Columbia River:							
Northport, Wash	—	6	8	14	0	0	0
Wenatchee, Wash	0.7	4	8	12	—	—	—
Pasco, Wash	—	17	93	110	0	0	0
McNary Dam, Oreg	—	20	56	76	0	1	1
Bonneville, Oreg	—	28	65	93	—	—	—
Clatskanie, Oreg	—	35	52	87	—	—	—
Connecticut River:							
Wilder, Vt	3.7	3	12	15	0	0	0
Northfield, Mass	0.4	4	10	14	—	—	—
Cumberland River: Clarksville, Tenn	0.9	—	—	—	—	—	—
Delaware River:							
Martins Creek, Pa	0.5	7	13	20	—	—	—
Trenton, New Jersey	0.7	—	—	—	—	—	—
Philadelphia, Pa	—	6	14	20	—	—	—
Escambia River: Century, Fla	0.5	6	14	20	1	0	1
Great Lakes:							
Duluth, Minn	0.1	1	7	8	0	0	0
Sault Ste. Marie, Mich	—	1	8	9	—	—	—
Milwaukee, Wis	0.8	2	6	8	0	1	1
Gary, Ind	0.1	6	12	18	0	1	1
Port Huron, Mich	0.8	3	13	16	—	—	—
Detroit, Mich	—	2	12	14	—	—	—
Buffalo, N. Y	0.8	6	13	19	0	1	1
Hudson River: Poughkeepsie, N. Y	2.5	—	—	—	—	—	—
Illinois River:							
Peoria, Ill	0.7	5	24	29	—	—	—
Grafton, Ill	0.6	16	18	34	1	3	4
Kanawha River: Winfield Dam, W. Va	—	6	14	20	—	—	—
Klamath River: Keno, Oreg	1.2	2	11	13	—	—	—
Little Miami River: Cincinnati, Ohio	0.6	20	26	46	1	2	3
Mississippi River:							
St. Paul, Minn	0.6	24	54	78	1	3	4
Dubuque, Iowa	—	4	38	42	—	—	—
Burlington, Iowa	1.9	21	35	56	1	0	1
E. St. Louis, Ill	—	136	33	169	4	2	6
Cape Giradeau, Mo	—	257	38	295	56	2	58
W. Memphis, Ark	—	27	35	62	—	—	—
Delta, La	1.8	15	31	46	0	2	2
New Orleans, La	—	24	26	50	—	—	—
Vicksburg, Miss	—	37	28	65	4	2	6
Missouri River:							
Williston, N. Dak	1.2	178	34	212	—	—	—
Bismarck, N. Dak	1.1	33	26	59	0	4	4
Yankton, S. Dak	2.5	14	36	50	—	—	—
Omaha, Nebr	0.7	192	55	247	—	—	—
St. Joseph, Mo	—	426	53	479	—	—	—
Kansas City, Kans	—	476	41	517	—	—	—
St. Louis, Mo	2.1	328	42	370	—	—	—
Missouri City, Mo	—	584	48	632	59	2	61
Monongahela: Pittsburgh, Pa	1.3	2	44	46	0	2	2
North Platte River: Henry, Nebr	1.3	26	56	82	2	22	24
Ohio River:							
Addison, Ohio	—	1	15	16	0	0	0
East Liverpool, Ohio	—	1	19	20	0	0	0
Huntington, W. Va	1.0	23	23	46	0	1	1
Cincinnati, Ohio	—	6	19	25	0	0	0
Louisville, Ky	—	7	26	33	1	0	1
Evansville, Ind	—	11	20	31	—	—	—
Cairo, Ill	—	1	20	21	0	1	1
Ouachita River: Bastrop, La	0.7	49	43	92	3	1	4
Pend Oreille River: Albeni Fall Dam, Idaho	—	7	8	15	0	<1	<1
Platte River: Plattsmouth, Nebr	—	344	62	406	23	1	24
Potomac River:							
Williamsport, Md	0.9	5	13	18	0	0	0
Great Falls, Md	—	2	17	19	0	0	0

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS—Continued

[Average concentrations in $\mu\mu c$/liter]

Station	Quarter ending Dec. 31, 1961	June 1962					
	Total Strontium-90	Beta activity			Alpha activity		
		Suspended	Dissolved	Total	Suspended	Dissolved	Total
Rainy River:							
Baudette, Minn	—	55	70	125	0	0	0
International Fls, Minn	0.3	8	30	38	0	0	0
Red River, South:							
Denison, Tex	—	16	42	58	1	1	2
Index, Ark	1.7	95	16	111	8	0	8
Alexandria, La	2.7	66	43	109	2	1	3
Rio Grande River:							
Alamosa, Colo	—	6	19	25	0	0	0
El Paso, Tex	—	22	21	43	—	—	—
Laredo, Tex	0.6	50	43	93	—	—	—
Brownsville, Tex	0.6	15	16	31	—	—	—
Roanoke River: John H. Kerr Resr. & Dam, Va	0.6	9	16	25	0	0	0
Sabine River: Ruliff, Tex	—	30	41	71	—	—	—
Sacramento River: Greens Landing, Courtland, Calif	—	16	0	16	1	0	1
San Juan River: Shiprock, N. Mex	—	54	12	66	18	2	20
St. Lawrence River: Massena, N. Y	1.6	4	11	15	—	—	—
Schuylkill River: Philadelphia, Pa	—	4	27	31	—	—	—
Savannah River:							
North Augusta, S. C	—	11	18	29	—	—	—
Port Wentworth, Ga	0.7	15	34	49	0	0	0
Shenandoah River: Berryville, Va	0.2	14	14	28	<1	<1	1
Ship Creek: Anchorage, Alaska	—	2	4	6	0	0	0
Snake River:							
Payette, Idaho	2.5	12	30	42	1	2	3
Wawawai, Wash	—	7	13	20	—	—	—
Ice Harbor Dam, Wash	—	4	15	19	<1	<1	1
Spokane River: Post Falls, Idaho	—	6	4	10	0	0	0
Susquehanna River:							
Sayre, Pa	—	5	12	17	—	—	—
Conowingo, Md	—	6	21	27	—	—	—
Tennessee River:							
Lenoir City, Tenn	—	5	10	15	0	0	0
Chattanooga, Tenn	0.5	0	18	18	0	0	0
Bridgeport, Ala	—	5	26	31	—	—	—
Pickwick Landing, Tenn	—	8	43	51	<1	0	<1
Tombigbee River: Columbus, Miss	0.2	50	26	76	1	0	1
Truckee River: Farad, Calif	0.1	5	21	26	1	0	1
Verdigris River: Nowata, Okla	—	92	57	149	6	2	8
Wabash River: New Harmony, Ind	—	218	34	252	10	0	10
Yakima River: Richland, Wash	0.6	3	10	13	0	<1	<1
Yellowstone River: Sidney, Mont	—	149	8	157	—	—	—

each new station, weekly samples are analyzed for alpha and beta activity.

If at any time activity significantly greater than the normal environmental levels has been noted, the rate of sampling and analysis has been increased to at least one every week. Since January 1959, a portion of each sample from all stations in the network has been composited into a three-month station sample for measurement of strontium-90 (*7*).

REFERENCES

(*1*) Public Health Service: National Water Quality Control Network, *Fallout From Nuclear Weapons Tests*, *1*:167–9, Hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (May 1959), Volumes 1 and 2, price $2.75 each, and Volumes 3 and 4, price $1.75 each.

(*2*) Division of Water Supply and Pollution Control, Public Health Service: *National Water Quality Network Annual Compilation of Data*, PHS Publication No. 663, 1960 Edition, Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

(*3*) Setter, L. R., and S. L. Baker: Radioactivity of Surface Waters in the United States, *Radiological Health Data*, *1*:20–31 (October 1960).

(*4*) Straub, C. P.: Significance of Radioactivity Data, *Journal of the American Water Works Association*, *53*:704 (June 1961).

(*5*) Setter, L. R., J. E. Regnier, and E. A. Diephaus: Radioactivity of Surface Waters in the United States, *Journal of the American Water Works Association*, *51*:1377 (November 1959).

(*6*) Robert A. Taft Sanitary Engineering Center Public Health Service: *Radionuclide Analysis of Environmental Samples*, Technical Report, R59–6 (1959).

(*7*) Straub, C. P., L. R. Setter, A. Goldin and P. F. Hallbach: Strontium-90 in Surface Waters in the U.S., *Journal of the American Water Works Association*, *52*:756 (June 1960).

SECTION V.—OTHER DATA

Whole Body Counting

Whole body counters are being applied where the detection of low levels of radioactivity in the human body is important. One example is the evaluation of hazards to radiation workers and the general population. These instruments are also used in human physiological and pathological investigations as well as in studies related to counter design for special purposes. Discussion and presentation of whole body counting results in previous issues of *RHD* have been limited to medical research programs employing thallium–activated sodium iodide crystals or liquid scintillation solutions. As other whole body counting data become available, they will be published.

CESIUM–137 IN MAN

June 1962 through August 1962
U.S. Army Medical Research Unit, Landstuhl, Germany

In 1955, cesium–137 was first detected in man by the Argonne National Laboratory. It emits a 0.661 Mev gamma photon, which can be quantitatively determined by a properly calibrated whole body counter. Since cesium is physiologically similar to potassium, and for the most part exists intracellularly, the cesium–137 levels are usually expressed in micromicrocuries per gram of potassium. The whole body counting facility at the Medical Research Unit, Landstuhl, Germany, in its program for measuring the cesium–137 levels in man, utilizes a liquid scintillation counter (*1*).

TABLE 1.—ASSAYS PERFORMED AT THE U. S. ARMY MEDICAL RESEARCH UNIT LANDSTUHL, GERMANY

Date	Number of subjects	Residence	Cesium–137 $\mu\mu$c/g K (average)	Percent MPBB*
June 1962	251	West Germany	32	0.15
July 1962	284	West Germany	38	0.18
August 1962	169	West Germany	44	0.20

* Percent maximum permissible body burden was calculated using 3 μc of cesium–137 as the general population maximum permissible whole body burden and 140 grams of potassium in the body of the "standard man." (See pp. 187 and 192 of Radiological Health Handbook, Office of Technical Services, U. S. Department of Commerce (1960), price $3.75.)

Previous coverage in *Radiological Health Data*:

Period	Issue
1958 and 1959	*October 1960*
1959 and 1960	*January 1961*
1958, 1959, and 1960	*April 1961*
First quarter 1961	*July 1961*
Second quarter 1961	*October 1961*
Third quarter 1961	*January 1962*
First quarter 1962	*August 1962*
Second quarter 1962	*October 1962*

REFERENCE

(*1*) *Radiological Health Data*, *2*:192–4 (April 1961).

External Gamma Exposure Dose Rate

RADIATION SURVEILLANCE NETWORK
September 1962

Division of Radiological Health, Public Health Service

Daily measurements of external gamma radiation are made at stations of the Radiation Surveillance Network to assure detection of any substantial deviations from normal background levels reported in recent years. Portable Geiger–Mueller survey instruments are used to obtain measurements at three feet above the ground surface. September 1962 data given in table 1 are characteristic of individual station observations during the past several years.

Correction for October issue: External gamma measurement for July 1962 at Lincoln, Nebraska should read 0.01 mr/hr.

TABLE 1.—EXTERNAL GAMMA RADIATION, RSN, SEPTEMBER 1962

Station location		Average (mr/hr)	Station location		Average (mr/hr)
Alaska:	Adak	0.01	Minn:	Minneapolis	0.01
	Anchorage	0.01	Miss:	Jackson	0.01
	Attu	0.01		Pascagoula	—
	Fairbanks	0.01	Mo:	Jefferson City	0.01
	Juneau	0.01	Mont:	Helena	0.03
	Kodiak	0.01	Nebr:	Lincoln	0.01
	Nome	0.01	Nev:	Las Vegas	0.01
	Point Barrow Isl	0.01	N. H:	Concord	—
	St. Paul Island	0.02	N. J:	Trenton	0.02
Ariz:	Phoenix	0.01	N. Mex:	Santa Fe	0.05
Ark:	Little Rock	0.01	N. Y:	Albany	0.02
Calif:	Berkeley	0.01		Buffalo	0.01
	Los Angeles	0.02		New York	—
Colo:	Denver	0.02	N. C:	Gastonia	0.02
Conn:	Hartford	0.01	N. Dak:	Bismarck	0.01
Del:	Dover	0.01	Ohio:	Cincinnati	—
D. C:	Washington	0.04		Columbus	0.01
Fla:	Jacksonville	0.01		Painesville	0.01
	Miami	0.01	Okla:	Oklahoma City	0.02
Ga:	Atlanta	[a]—		Ponca City	0.02
Guam:	Agana	—	Ore:	Portland	0.02
Hawaii:	Honolulu	0.01	Pa:	Harrisburg	0.01
Idaho:	Boise	0.02	P. R:	San Juan	0.01
Ill:	Springfield	0.01	R. I:	Providence	0.02
Ind:	Indianapolis	0.01	S. C:	Columbia	0.02
Iowa:	Iowa City	0.01	S. Dak:	Pierre	0.02
Kans:	Topeka	0.02	Tenn:	Nashville	0.01
Ky:	Frankfort	0.01	Tex:	Austin	0.01
La:	New Orleans	0.02		El Paso	0.02
Maine:	Augusta	0.02	Utah:	Salt Lake City	0.02
	Presque Isle	0.02	Vt:	Barre	0.02
Md:	Baltimore	0.02	Va:	Richmond	0.01
	Rockville	—	Wash:	Seattle	0.01
Mass:	Lawrence	0.02	W. Va:	Charleston	—
	Winchester	0.02	Wis:	Madison	0.02
Mich:	Lansing	0.02	Wyo:	Cheyenne	0.01

[a] Dash indicates no data received.

Factors Influencing Gamma Ray Exposure Dose to Nonurban Populations from the Deposition of Nuclear Test Fallout* (*1*)

Harold A. Knapp**

The Problem

The deposition of radioactive fallout on the earth's surface creates a field of penetrating gamma radiation to which all living things in the environment are exposed. At various times and places this field has been directly measurable with instruments, and has been clearly distinguishable from natural background radiation. Except for persons living in the immediate area of the Nevada Test Site, however, there is no simple, sufficiently sensitive radiation detector which may be attached to individuals in the population to make a direct measurement of the external gamma dose they receive from fallout. For this reason it is necessary to calculate the doses and dose rates to which segments of the population in various areas of the country are subjected from various radioactive materials deposited on the ground. The calculations may involve a very complex series of assumptions starting with the quantity of radioactive materials produced at different places and under varying conditions. Or, they may start with a measurement of some aspect of fallout deposition, e.g. the amount of strontium–90 or zirconium–95 deposited per square mile, the total beta activity brought to earth in a rainfall, or the measurement of the gamma dose rate above an open surface.

It is a relatively straightforward matter to compute the dose rate 3 feet above a flat, impenetrable surface uniformly contaminated with a specific nuclide such as cesium–137. But fallout consists of many nuclides, and is rarely deposited uniformly on a flat, impenetrable surface. It irradiates people who spend a significant part of their time in buildings, and at varying distances above the ground.

One purpose of this review is to summarize available information on the reduction of the average external gamma dose rate due to fallout from nuclear weapons tests. These reductions may be attributed to weathering, terrain roughness, and the shielding effect of buildings. A second purpose is to note what can be said as to the distribution of external gamma doses from fallout among the population, composed as it is of persons who spend varying amounts of time out–of–doors and in structures with different shielding characteristics.

It is necessary to distinguish at least four different dose rates and associated doses of interest:

1. The dose rate and resulting accumulated doses which would be experienced in air three feet above an infinite, flat, impenetrable surface if the concentration of fallout on this hypothetical surface were the same per unit area as the fallout actually deposited on the earth's surface. Such a dose rate is usually designated the *infinite plane* dose rate.[1] It is determined solely by the radionuclide composition of the debris and by its density per unit area, since this determines the number and energy of the photons passing through a unit volume of air three feet above the infinite plane.

2. The dose rate and resulting doses which are experienced in air, out–of–doors, three feet above the ground as the result of the deposition of a specified amount of fallout per unit area. This dose rate presumably depends on the outdoor area considered; for example, a city street, a golf course, a forest, or a plowed field. It is

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* Summarized from *Gamma Ray Exposure Dose to Nonurban Populations from the Deposition of Nuclear Test Fallout* in AEC–TID–16457 (July 1, 1962); abridged summary prepared by Dr. Harold A. Knapp.

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[1] Strictly speaking this is an air ionization rate, measured in roentgens/hour where 1 roentgen is defined as the quantity of X— or gamma radiation such that the associated corpuscular emission per 0.001293 grams of air produces, in air, ions carrying 1 electrostatic unit of electricity of either sign. (The mass of 1 cm^3 of dry atmospheric air is 0.001293 grams at 0° C and 760 mm of mercury pressure.) The unit of absorbed dose is the rad, defined as that amount of ionizing radiation which causes 100 ergs of energy to be absorbed per gram of tissue. An air exposure of 1 roentgen is roughly equivalent to an absorbed dose of 1 rad in human tissue, although some parts of the body are significantly shielded by other parts.

usually less than the corresponding infinite plane dose rate, depending on the shielding afforded by irregularities in the terrain, by objects above ground, and by the leaching of the radioactive materials into the soil by rainfall. However, special terrain situations can *increase* the infinite plane dose rate at particular locations by focusing radiation or concentrating the fallout particles. This out–of–doors dose rate is here designated the *open field* dose rate. In order for the concept to have a precise meaning, it would be necessary to define a "standard open field" and designate the conditions of this field. The gamma dose rate would be appreciably affected, for example, if the field were covered by three feet of wet snow. The center of a football field or any similar, more or less level, open area such as is often found in pastures, golf courses, or around large institutions would probably be sufficiently standard, as well as being a place where measurements might actually be made. Most fallout computations implicitly assume that the concept of a standard or average open field is meaningful and useful, and that the doses and dose rates in air three feet above this field resulting from a specified level of fallout contamination are a suitable measure of the degree by which the environmental gamma background has been changed for wildlife or for a person who remained out–of–doors continuously in a rural area. In terms of the computations, this means that there exists a constant factor "f" by which an infinite plane dose averaged over an area may be multiplied to give a representative environmental dose for that area.

3. The roentgen doses and dose rates to which people are actually exposed when living in an area where the average deposition of radioactive fallout per unit area has been measured or computed. Since people live and work in buildings with widely varying radiation shielding characteristics, and since they spend different amounts of time out–of–doors, it is clear that they would experience different levels of exposure from fallout, even if the fallout were uniformly deposited over the area. It would be logical to ask what average reduction in the open field dose occurs from these causes alone, i.e. without regard to local variations in the fallout deposition per unit area, and to what distribution of doses it gives rise. To obtain the actual distribution of doses it would then be necessary to make detailed studies of the local variations in the distribution of fallout due to natural causes and of the time spent in each location with differing deposition levels. Since available data (*2*) are based on the distribution of measured exposures in a population for a derived average fallout level, and inasmuch as the lack of data on small scale variations in outdoor fallout levels precludes (at least for the present) the usefulness of a concept which allowed for such variations, estimates of the actual distribution of dose to persons are here based on the average concentration of radioactive materials in the area of interest. This concept is simpler to work with, but it could introduce errors of concept or prediction. One can speculate that apart from the shielding obtained by being inside buildings, the same average fallout level in an open prairie and on a wooded mountainside would lead to different exposures of rural populations living in these areas, but it is difficult to try to specify what these differences would be. It is assumed here that it is possible to calculate doses to people in a suitably large area on the basis of an average deposition level over the area, but one should not discount the possibility that this assumption may lead to significant errors if it is assumed that the same factor relating average deposition and average dose to people holds for different areas.

4. The doses from external gamma radiation actually received by different body organs, such as the thyroid, the bone marrow, and the gonads. To a certain extent the internal organs of the body are screened by the body itself, the relative reduction in the dose rate depending upon the energy of the gamma photons and the amount of tissue through which the radiation from various directions must pass. Such reduction factors for various body organs are not further considered here, nor is the fact that different body organs are at different heights above the ground, and that these heights vary for persons of different ages.

Discussion

The principal data upon which the relations between the infinite plane dose and the actual dose to a non-urban population have been esti-

mated were collected by U.S. Public Health Service. As reported by Reed (*2*):

p. 5 "The U.S. Public Health Service Off-Site Rad-Safety Organization furnished film badges to a large number of people in and around Nevada during Operation Plumbbob (1957). These badges were used to measure population exposure to test fallout. A large number of badges were placed at fixed points in and around inhabited places to measure area fallout exposure. The USPHS collected and developed these badges and listed the measured radiation doses. These numbers were added to dose from earlier operations to show maximum total lifetime doses to various communities. *The listing showed that badges on people averaged only two-thirds as much radiation as was recorded by badges mounted at fixed points out–of–doors.*"

p. 6 "Individual comparisons between badge and map doses show a broad range of differences. Under what seem to be similar conditions, different persons received different measured doses. This scatter in results of comparisons is important in finding or forecasting the most radiation that human beings might get from living in a fallout pattern."

p. 10 ". . . it was found that most badge collections for specific locations had a distribution of non-zero readings which closely followed the logarithmic normal distribution. This distribution is commonly valid when measuring errors are nearly as large as measured magnitudes, and negative values are not possible. *What this means is that the probability of observing a value greater than X times the mean value is the same as the probability of observing a value smaller than 1/X times the mean value.*"[2]

Reed's report does not give a detailed account of the conditions under which the fixed point and personal film badges were exposed, nor does it state exactly how the fixed badges were located with respect to structures which could provide possible shielding. Further, it is not certain that the badges represented a suitable average of the open field dose in the areas where badges on people were also exposed, although it is assumed here that this is the case. Thus it is *tentatively* concluded that the average shielding effect of buildings on a population reduces the average exposure to ⅔ of the open field exposure. If terrain roughness reduces the open field dose to ¾ of the infinite plane dose, Reed's result would lead to the conclusion that the population was exposed on the average to ¾ x ⅔ = ½ of the infinite plane dose for the first year, providing weathering is not an important factor during this time. This conclusion assumes that for world–wide stratospheric fallout the relations between the infinite plane dose, the open field dose, and the dose received by the U.S. population generally are the same as those which describe these doses in the communities around the Nevada Test Site from the tropospheric fallout from Nevada tests. This is a big assumption which needs detailed investigation, but presumably it is better than no information at all.

Three conclusions from Reed's report were accepted without change and used to draw specific conclusions concerning the distribution of dose amongst the population.

They are:

(1) that the average value (the arithmetic mean) of the badges on people was two–thirds the average value recorded by the badges mounted at fixed points out–of–doors, and that these badges mounted out–of–doors measured the open field dose,

(2) that the distribution of doses to people from Nevada fallout is accurately described by the film badge samples, for the time during which the badges were exposed, and that this distribution is, within the limits considered later, lognormal, and

(3) that Reed's computation of the parameter describing the spread in values of the doses to the population (e.g., the fraction which is x times and $1/x$ times the *median* value, called the *mean* value by Reed) is correct.

These conclusions and their implications are understandable only in terms of the definition and properties of the lognormal distribution.

A statistical variable x which takes on only positive values is said to be lognormally distributed if the natural logarithm of x (here

[2] Reed's use of the term *mean* value here is not strictly correct. It is the *median* value, of the lognormal distribution which has this property.

denoted as $\ln x$) is normally distributed. Letting $y = \ln x$, this means that there exists a mean m and a standard deviation σ such that the distribution function for y, $F(y)$, is given by

$$F(y) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}[(y-m)^2/\sigma^2]}$$

From the properties of distribution functions in general this means that the probability that y will lie between y_1 and y_2 is

$$\int_{y_1}^{y_2} F(y)\, dy.$$

The distribution function for x, $f(x)$ is then determined to be

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{1}{2}[(\ln x-m)^2/\sigma^2]}$$

and the probability that x will lie between x_1 and x_2 is

$$\int_{x_1}^{x_2} f(x)\, dx.$$

Letting D be the infinite plane dose from time of arrival to 1 year, the values of σ and m obtained from Reed's report are then given by the relations

$$e^m = .326D,$$

and

$$e^\sigma = 2.55,$$

where $e = 2.7183$ is the base of natural logarithm.

Conclusions

1.There is little definitive evidence to indicate the extent to which the theoretical air dose three feet above a smooth, impenetrable, infinite plane contaminated with the measured surface concentration of fallout should be reduced to obtain the average gamma ray exposure of the population. It has often been assumed that the average dose to people is from $\frac{1}{5}$ to $\frac{1}{10}$ the infinite plane dose. It is tentatively concluded that for the first year following fallout, the average dose to the non-urban population of the U.S. lies between $\frac{3}{10}$ and $\frac{5}{10}$ of the infinite plane dose. Film badge readings on people living in the vicinity of the Nevada Test Site are reported (*2*) as averaging two-thirds the average reading on badges placed at fixed locations out–of–doors. This result, together with the conclusion that due primarily to terrain roughness the open field dose for the first year following deposition would average $\frac{3}{4}$ of the infinite plane dose, lead to the tentative conclusion that for a year following deposition, the average dose to a population group in the U.S. can be as much as $\frac{2}{3} \times \frac{3}{4} = \frac{1}{2}$ the infinite plane dose for time periods extending up to 1 year following detonation. No attempt is made to estimate the corresponding reduction for persons who live in cities. That could be much less.

2. For a radionuclide such as cesium–137 (half–life 30 years) which delivers its potential 30– and 70–year exposures slowly over a lifetime, the total dose depends critically on long–range weathering effects. If the actual dose rate to people from cesium–137 released to the environment were to be reduced by a factor of 2 every 10 years instead of every 30 years as dictated by radiological decay, the lifetime (70–year) dose from material which originally gave a dose rate of 1 mrad/year would be cut from 34.6 mrad to 14.2 mrad. Were the dose rate to decrease by a factor of 2 every 5 years, the lifetime dose would be reduced to 7.2 mrad. Thus it is possible that weathering considerations may have a large influence on the potential dose received from cesium–137, even though it appears that they have little effect on the potential dose from a short– or intermediate–lived nuclide such as zirconium–95 (half–life 63 days).

3. The conclusions drawn from analysis of film badges in the Nevada radiation safety monitoring program suggest that the distribution of dose to a population in a more or less uniformly contaminated area is, within uncertain limits, approximated by a lognormal distribution function in such a way that $\frac{1}{6}$ of the population receives at least 1.7 times the average dose. If this lognormal distribution function is extrapolated, it leads to the conclusion that 2.5 percent of the population receives at least 4 times the average exposure, but the validity of such an extrapolation is unknown.

4. The air ionization rate r at 3 feet above a flat, impenetrable, infinite plane uniformly con-

taminated with M megacuries of a radioactive nuclide per square mile (or C curies per square meter) may be approximated by $r = 7.7\ M\ \gamma$ (or $r = 3.0\ C\gamma$) roentgens/hour, where γ is the average gamma energy released per disintegration, expressed in Mev. This formula is approximately correct when the energy of the individual gamma photons (as opposed to the total gamma photon energy emitted per disintegration) lies in the range from 0.1 to 1.5 Mev. It is generally applicable to individual fission products, or to collections of fission products. It gives ionization rates 10 percent higher than those indicated in the "Effects of Nuclear Weapons" (*3*). For some applications it is more convenient to redefine M as the total number of gamma megacuries per square mile and γ as the average energy of the gamma photons, but one must take care to be consistent as to which scheme is being used.[3]

5. Following a 1954 estimate by J. Hill of the RAND Corporation (*4*), the dose rate three feet above an open field is estimated to be reduced by terrain roughness to approximately 87 percent of what it would be above an infinite, smooth plane. In steep, rough terrain, Hill indicates a reduction to about 58 percent of the infinite plane value, and in residential areas to approximately 70 percent to 80 percent of the infinite plane value.

6. Reduction of the external gamma dose rate by weathering—that is the leaching of radioactive particles into the soil by rainfall—is highly uncertain, but from the evidence available it is concluded that weathering cannot be expected to make an appreciable difference for about a year, and that for several years thereafter the open field dose rate would not be reduced by more than 30 percent from this effect.

[3] It is often difficult to find agreement between authors as to the value of γ appropriate for specific gamma emitting radionuclides. The computation of γ may in fact be quite difficult, and the nuclear data upon which the computations are based changes frequently.

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(*3*) U.S. Department of Defense: *Effects of Nuclear Weapons*, U.S. Atomic Energy Commission, Washington, D.C. (April 1962), p. 492.

(*4*) J. Hill: Effects of Environment in Reducing Dose Rates Produced by Radioactive Fallout from Nuclear Explosions, *RAND RM–1285*, (September 28, 1954).

Iodine–131 in Milk and Vegetables Associated With July 1962 Fallout in Utah*

The July 8, 1962 Radiation Surveillance Network (RSN) report of a relatively high field estimate of gross beta activity on an air filter sample collected in Salt Lake City, Utah, set in motion intensified milk and other environmental samplings in that area. The Salt Lake City cooperative pasteurized milk sampling effort of the Utah State and Salt Lake City Health Departments and the Public Health Service was stepped up to a daily sampling schedule (*1*). Additionally, the Food and Drug Administration began collecting vegetable samples from the growing areas surrounding Salt Lake City. Available data from these sampling activities, the U.S. Weather Bureau and the U.S. Atomic Energy Commission reports on nuclear detonations at the Nevada Test Site, have been assembled and are presented in this report.

Certain public health protective measures were initiated by the Salt Lake City and Utah State Health Departments in the Salt Lake City milk collection area on August 1, 1962. The measures included the diversion of fluid milk to manufacturing plants and the use of stored feed for the cattle in place of pasture grass. The effect of these measures in reducing radioactivity concentration in milk is not considered in this report since the data presented concern primarily the period before August 1.

The purpose of this article is to present the time sequences of various events which might have been associated with the July increase of iodine–131 in Salt Lake City milk and leafy vegetables, as a step in further relating some of the factors that may lead to the appearance of iodine–131 in milk and other foods.

Whenever radiological contamination occurs near a test site there is great interest in trying to relate the contamination to a specific nuclear detonation. When multiple detonations occur in short intervals, this invariably leads to differences of opinion as to the origin of the specific contaminated radionuclide. The data presented here is an effort to consider this situation on the basis of data normally available to the public health agencies. It is hoped that this information, with that of other scientific contributors and reviewers, may help us to better understand the events that took place in the interest of both public health agencies and those responsible for the nuclear testing program which is essential for national defense.

IODINE–131 IN PASTEURIZED MILK

Division of Radiological Health,
Public Health Service

The Salt Lake City station of the Public Health Service Pasteurized Milk Network began daily sampling of pasteurized milk on July 10, 1962, as a result of an alert from the Radia-

* Compiled and developed by Mr. Robert G. Bostrom, *RHD* Staff.

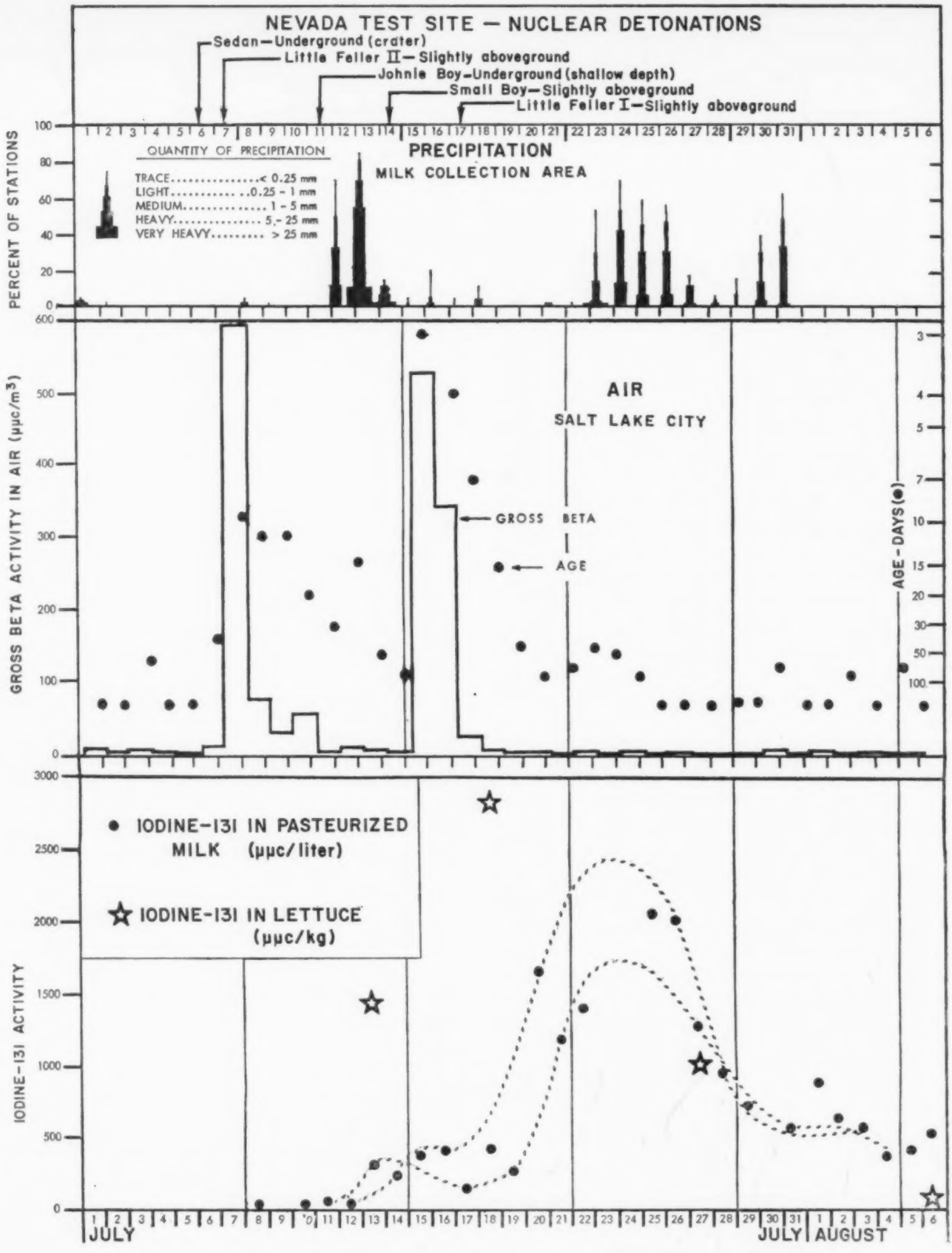


Figure 1.—CHRONOLOGICAL COMPARISON OF DATA, UTAH, JULY 1962

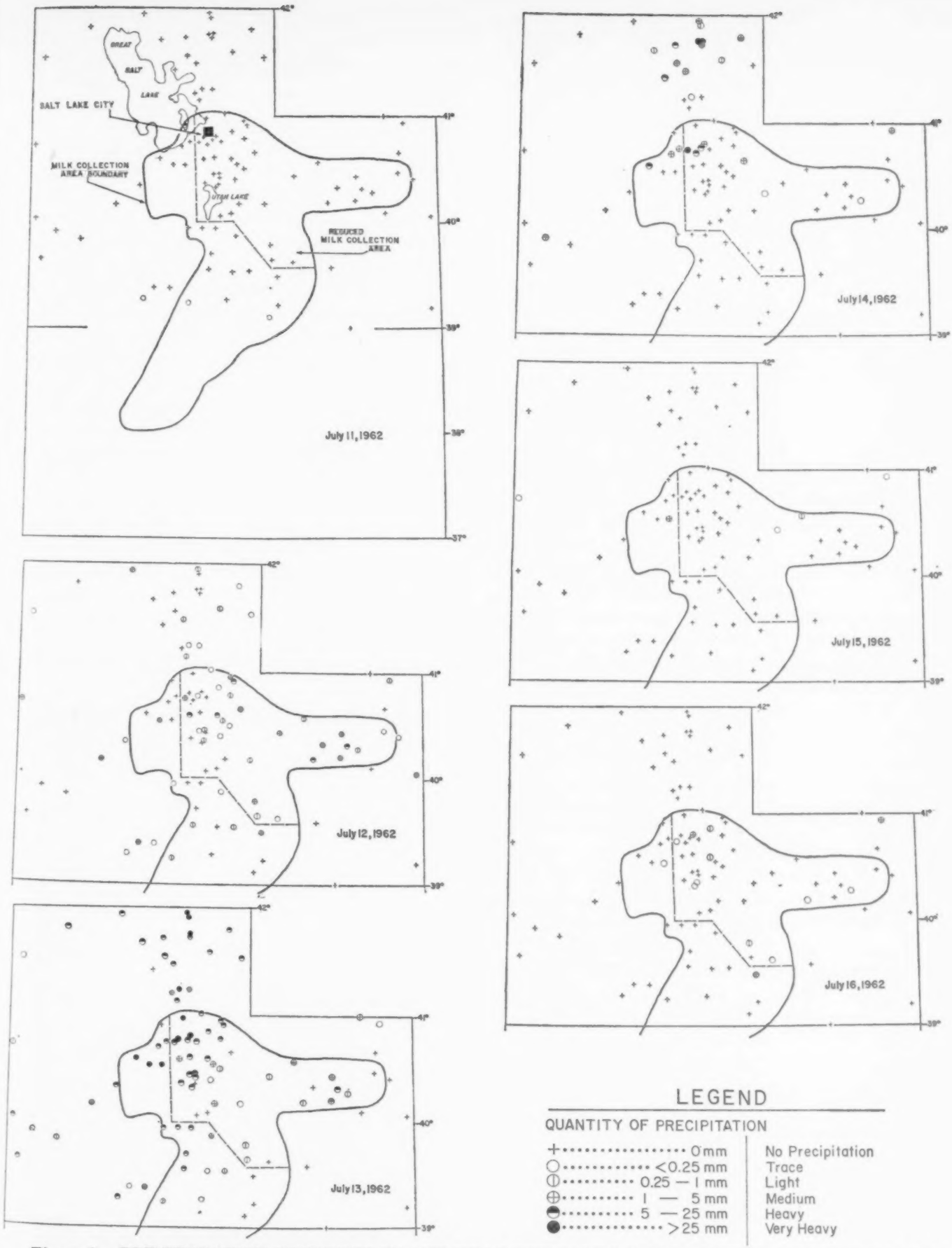


Figure 2.—PRECIPITATION RECORDED IN AND NEAR THE SALT LAKE CITY MILK COLLECTION AREA

tion Surveillance Network field estimate of gross beta in air on July 8. Daily iodine–131 concentrations in Salt Lake City pasteurized milk for July and a portion of August 1962 are tabulated in table 1 and presented graphically in figure 1.

The PHS milk sample is a composite of samples of pasteurized milk from nearly all of the dairies (pasteurizing plants) in Salt Lake City. Each dairy receives its raw milk in large tank trucks from farms on regular alternate day schedules.

The milk collection area of Salt Lake City extends approximately 150 miles to the east and 220 miles to the south of the city as shown in figure 2. The area includes both irrigated valleys and intervening mountain ranges. It is believed that at least 90 percent of the area's milk production is represented by a portion of the milk collection area east of Salt Lake City and Lake Utah. This section of the milk collection area, delineated by a dashed–line boundary in figure 2, is used as the basis for the precipitation analyses shown in figure 1 and table 3.

The milk flow pattern in the Salt Lake milk collection area is complex and does not lend itself readily to a simple outline nor a scientifically representative sampling procedure. However, the pattern can be outlined in a general way and data from the samples collected are useful for comparative purposes.

The tank trucks pick up from roughly half of the farms on odd days of the month and from the remainder on even days. Each collection is composed of a mixture of milk from 4 milkings, including the morning milking of the day of collection and the evening milking of the day the previous collection was made. The time interval between morning milking (usually about 6:00 a.m.) on the day of collection and the time of delivery of the milk to the dairy varies from about 6 to 18 hours, depending on the area of collection for the individual truck. Flow-through time in the dairy for pasteurizing, bottling, and handling takes as little as two hours. The PHS samples are usually collected in late afternoon so that a large portion of the day's milk collection is represented. Samples collected on Sundays and Wednesdays, however, represent the previous day's collection since the pasteurizing plants are not in operation on those days.

RADIOACTIVITY IN LETTUCE

Division of Pharmacology,
Food and Drug Administration

Several types of leafy vegetables were sampled by the Food and Drug Administration in the vicinity of Salt Lake City during July and August in response to the alert signalled by the peaks of gross beta in air detected in that city on July 8 and 16.

Lettuce, including leaf lettuce and endive, but not head lettuce, was selected for sampling purposes. Lettuce samples from six farms in the vicinity of Salt Lake City were collected on each of the four sampling dates, July 13, 18, 27, and August 6. The samples (unwashed) were analyzed for iodine–131, strontium–90, and total beta activity. Iodine–131 was determined by measurement of the 0.36 Mev peak in the gamma spectrum using a 3″ X 3″ thallium activated sodium iodide crystal and a 400-channel analyzer. Average concentrations for each set of six samples are presented in table 2. The profile of iodine–131 concentration in lettuce (including endive) is plotted in figure 1.

TABLE 1.—IODINE–131 IN PASTEURIZED MILK AT SALT LAKE CITY, UTAH

Date	Iodine–131 ($\mu\mu$c/liter)	Date	Iodine–131 ($\mu\mu$c/liter)
July 1, 1962	[a] —	July 20, 1962	1,660
2	—	21	1,190
3	<10	22	1,390
4	—	23	—
5	—	24	—
6	<10	25	2,050
7	—	26	2,000
8	<10	27	1,290
9	—	28	960
10	20	29	730
11	60	30	—
12	30	31	570
13	200	August 1, 1962	890
14	250	2	640
15	390	3	590
16	410	4	370
17	160	5	410
18	450	6	520
19	280		

[a] Dash denotes no samples collected.

TABLE 2.—RADIOACTIVITY IN LETTUCE SAMPLES COLLECTED IN THE SALT LAKE CITY AREA

[concentrations in $\mu\mu$c/kg (fresh weight)]

Date [a] of harvest 1962	Total beta	Strontium–90	Iodine–131
July 13	25,650	26	1,437
18	44,000	63	2,812
27	18,450	53	1,014
August 6	8,100	33	3

[a] Six samples were collected on each date and the results averaged.

AIR AND PRECIPITATION FACTORS

Division of Radiological Health,
Public Health Service

Continuous daily filter samples of airborne particulates are collected by the Radiation Surveillance Network in Salt Lake City and in 70 other stations throughout the United States. A field estimate of the gross beta activity on the filter is made before sending the filter to the central laboratory for more accurate determination of beta activity and estimation of age of fission products. Although the field estimates served as the alert signal, the final laboratory measurements of gross beta activity in Salt Lake City surface air are plotted in figure 1. The estimated age of fission products, also plotted in figure 1, is determined by the Way–Wigner method discussed on page 462. This method does not give accurate age estimates for underground detonations, presumably because of fractionation of fission products and neutron activation of soil particles. However, the estimated ages presented in figure 1 may at least indicate general freshness of fission product activity. Examination of this figure shows that peaks of young fission product activity occurred on July 7–8 and July 15–17.

To give a broader geographical picture of atmospheric radioactivity, maps of the United States with beta concentration contours and age of fission product contours for a limited number of days are presented in figure 5. Also included in this figure are maps showing precipitation depth, other meteorological information, and precipitation fission product activity.

Precipitation samples are also collected by RSN in Salt Lake City and analyzed for gross beta and age of fission products (see table 3). However, during July, only two days (July 13 and 14) yielded enough rain to sample. Further, the activity in these precipitation samples cannot be considered representative of the entire milk collection area.

Precipitation depth measurements made by 100 Weather Bureau cooperative stations in northern Utah (*3*) are given day by day on the maps in figure 2. Table 3 summarizes the data in terms of estimated average intensity of pre-

TABLE 3.—PRECIPITATION IN THE SALT LAKE CITY MILK COLLECTION AREA, JULY 1962

Date [a] July, 1962	Precipitation in abbreviated milk collection area (43 Weather Bureau cooperative stations)		Salt Lake City precipitation (RSN)		
			Depth (mm)	Fission product activity	
	Percent of stations reporting some precipitation	Average precipitation reported (mm)		Deposition ($m\mu c/m^2$)	Age (days)
1	7	3.0	—	—	—
2	2	trace	—	—	—
3	— [b]	—	—	—	—
4	—	—	—	—	—
5	—	—	—	—	—
6	—	—	—	—	—
7	—	—	—	—	—
8	5	1.1	—	—	—
9	2	trace	—	—	—
10	—	—	—	—	—
11	—	—	—	—	—
12	70	2.8	—	—	—
13	84	10.0	12.3	97	28
14	16	9.5	8.7	41	46
15	5	0.2	—	—	—
16	21	0.2	—	—	—
17	5	trace	—	—	—
18	12	1.2	—	—	—
19	—	—	—	—	—
20	—	—	—	—	—
21	2	3.5	—	—	—
22	2	trace	—	—	—
23	54	2.0	—	—	—
24	68	2.2	—	—	—
25	60	2.5	—	—	—
26	56	2.2	—	—	—
27	19	3.5	—	—	—
28	5	1.5	—	—	—
29	16	0.2	—	—	—
30	40	1.5	—	—	—
31	63	1.2	—	—	—

[a] The data is that of the end of the sampling period: 6:00 p.m. for Weather Bureau cooperative stations and 8:00 a.m. for the RSN station.
[b] Dash denotes no precipitation reported.

cipitation in the milk collection area and the estimated percent of milk collection area having rain.[1] Although no radioactivity measurements have been made of these precipitation samples, the activity recorded in the Salt Lake City precipitation, together with the concurrent presence of precipitation in other parts of the milk collection area suggests the possibility of deposition of fresh fission products.

Little or no precipitation occurred during the first part of the month on the Salt Lake City milk collection area until the widespread rains of July 12 and 13. For the rest of the month scattered trace and light rains occurred from time to time throughout the area.

METEOROLOGICAL TRAJECTORIES OF DEBRIS FROM NUCLEAR DETONATIONS

Weather Bureau,
U.S. Department of Commerce

The Atomic Energy Commission announced that five nuclear detonations conducted at the Nevada Test Site during July 1962 released radioactivity into the atmosphere (see table 4).

Meteorological trajectories (see figure 3) of the air, which carried the debris from the various detonations listed, have been computed by the Weather Bureau Research Station, Las Vegas, Nevada. These trajectories depict the path of air mass for constant heights above mean sea level (MSL), which may contain gaseous or small-particle debris which has a negligible fall rate. The meteorological trajectories are based on the wind analyses for the various levels and take into account the temporal and spatial changes in the wind. Meteorological trajectories are, of course, subject to error, particularly over regions of sparse data or in areas of rapidly changing or complex flow patterns.

[1] The milk collection area used here is the portion of the area north and east of the dashed-line in figure 2. This area is believed to represent more than 90 percent of the regular Salt Lake City milk supply.

ANALYSIS OF DATA

Milk

Iodine–131 kinetics in the lactating cow have been studied by various investigators. Garner has detected iodine–131 in milk in as little as 30 minutes after the cow's ingestion of 1 mc of iodine–131 (*4*). Analyses on milk from three herds of cows (three different States) that were removed from pasturage and put on stored feed showed initial declines of the iodine–131 concentration corresponding to effective half–lives of 16 hours to 2 days.[2] The milk from one of the herds was analyzed daily and showed an effective half–life for iodine–131 of 16 hours for the first 3 or 4 days followed by an effective half–life of between 7 and 8 days.[2] For this analysis a one–day effective half–life for iodine–131 in udder milk and a 7–day half–life in pasturage are assumed. Using these values it is estimated that a cow's continous ingestion of pasturage initially contaminated with iodine–131 would result in a peak of activity in milk in 3.3 days.[3] Using these assumed

[2] Personal communication from Dr. C. P. Straub, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

[3] $$t(C)_{max} = \frac{3.323\ T_A\ T_B}{T_A - T_B} \log \frac{T_A}{T_B}$$

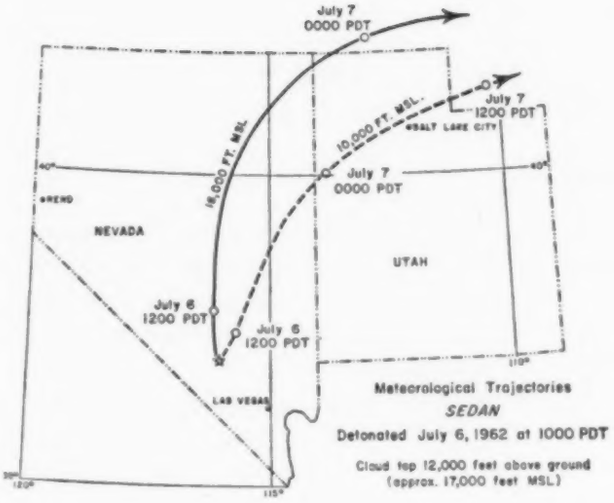
Overman, Ralph T., and H. M. Clark: *Radioisotope Techniques*, McGraw-Hill, (1960), p. 303.

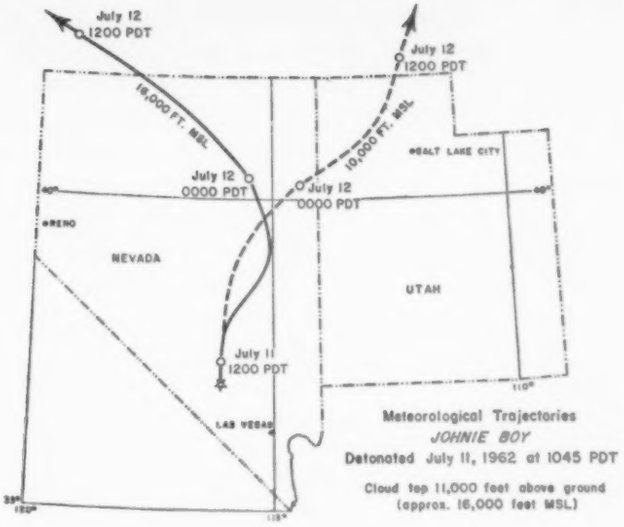
(By analogy, C is the concentration of iodine–131 in udder milk and therefore, $t(C)_{max}$ is the time at which the concentration in udder milk is a maximum, T_A is effective half-life of iodine–131 in pasturage and T_B is effective half-life of iodine–131 in udder milk.)

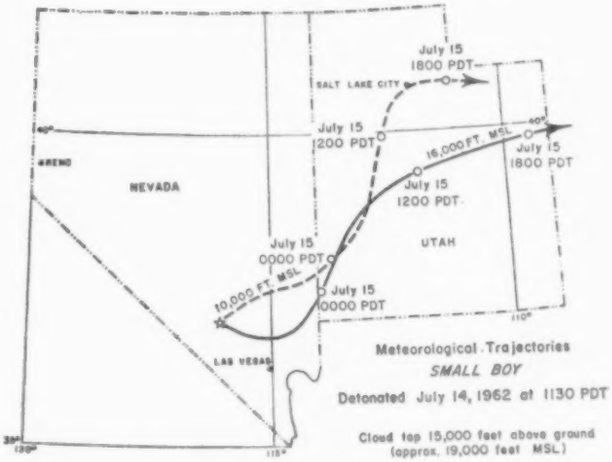
TABLE 4.—NUCLEAR TESTS AT NEVADA TEST SITE WHICH RELEASED RADIOACTIVITY TO THE ATMOSPHERE IN JULY 1962

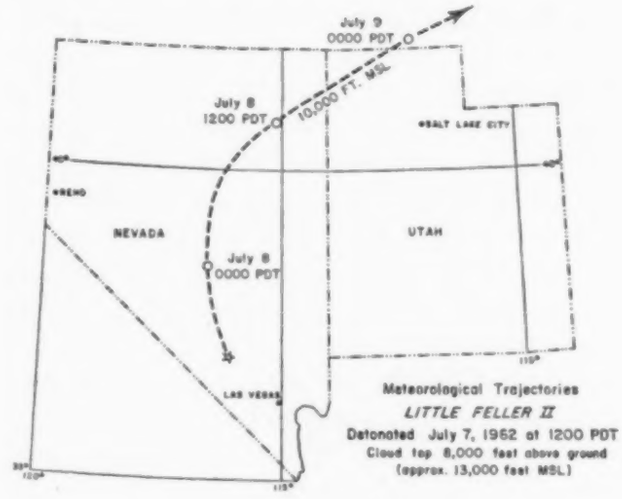
Date	*Time (PDT)*	*Name*	*Type*	*Yield*	*Approximate Cloud Height Above Ground*
6 July	1000	Sedan*	635 feet underground	about 100 Kt	12,000 feet
7 July	1200	Little Feller II	slightly above ground	low	8,000 feet
11 July	0945	Johnie Boy	shallow underground	low	11,000 feet
14 July	1130	Small Boy	a few feet above ground	low	15,000 feet
17 July	1050	Little Feller I	slightly above ground	low	10,000 feet

*AEC news release. "The device used was a relatively 'clean' thermonuclear device in which fission contributed less than 30 percent of the total yield." . . . "As expected, most of the radioactivity produced by the explosion was trapped underground. A precise determination of the percentage of escaping radioactivity cannot be obtained from the available preliminary data, but these data do show that there was no major deviation from the prediction that about 95 percent of the radioactivity would be trapped in the ground."









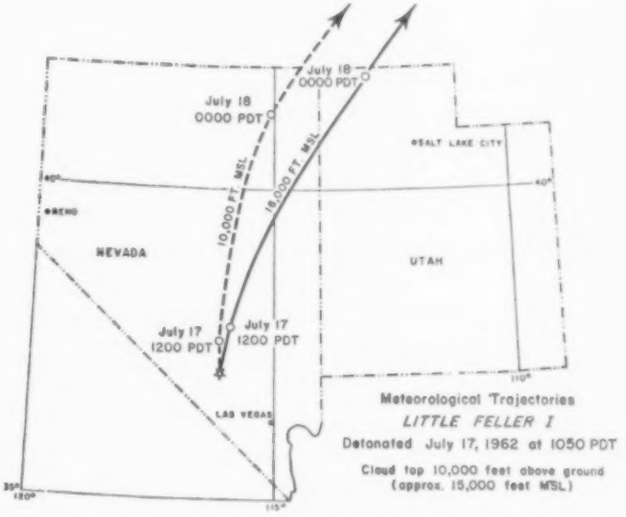


Figure 3.—METEOROLOGICAL TRAJECTORIES OF RADIOACTIVITY FROM NUCLEAR DETONATIONS

values, the hypothetical curves in figure 4 were drawn to depict possible time relationships between initial fallout and appearance and peaks of iodine–131 in pasteurized milk. The shapes of these curves may possibly be modified by such variables as (1) reinforcement of activity in pasturage by continual deposition; washoff of activity by rains of low activity; and (3) growth of new grass after deposition. The "case A" curves represent a hypothetical situation in which most of the iodine–131 on pasturage was washed off very shortly after it was initially deposited. In "case B," however, the deposited iodine–131 remained on the pasturage for several days after deposition, decreasing in concentration with an effective half–life nearly equal to the physical half–life of 8 days. Here a 7–day half–life was assumed allowing for some effect from plant growth.

Depending on the tank truck milk collection schedules, the time sequence for pasteurizing, and the PHS sample collection, the time required for milk from a given milking to reach a PHS pasteurized milk sample may vary from 10 hours to 3 days. This time delay for storage, transportation, and processing is also depicted in figure 4.

By interrelating the curve for iodine–131 in udder milk with the time lag for storing, transporting, and processing (figure 4), it may be expected that some iodine–131 may be detected in a PHS sample collected as little as 12 hours after the radioactivity was deposited on the pasturage. Furthermore, the maximum concentration of iodine–131 in a series of PHS pasteurized milk samples, assuming the effective half–life of one day for iodine–131 in udder milk, would probably occur 3 to 6 days after the deposition of activity under the conditions depicted in figure 4.

Iodine–131 concentrations in pasteurized milk during July can be roughly separated into four general phases: (1) *initial appearance*, July 8–12, with concentrations ranging from 20 to 60 μμc/liter; (2) *plateau stage*, July 13–19, 160–450 μμc/liter; (3) *peak stage*, July 20–26, 1190–2050 μμc/liter; and (4) *decline stage*, July 27–31, with a downslope approximating a 3–day half–life.

The question may be raised whether the alternate day milk collection schedules may affect the daily pasteurized milk sample iodine–131 activities because of day-to-day differences in the geographical source of milk. The two broken line curves in figure 1 reflect these activities. One curve represents iodine–131 in milk sampled on even dates in July and the other on odd dates (excluding Sundays and Wednesdays because of dairy plant shutdown). The successive variations between the two curves suggest that the alternate day milk collection schedules may influence the iodine–131 values in the composite pasteurized milk sample.

Lettuce

A comparison of the iodine–131 concentrations in the four sets of lettuce samples leads to the question of what may have occurred during the time periods between samplings to yield the observed concentrations.

If lettuce were sampled daily, the resulting iodine–131 profile would probably have characteristics similar to the hypothetical iodine–131 profile for pasturage in figure 4. Sharp decreases could occur as a result of washoff by rains of low radioactivity. During the periods between the depositions or washoffs, the profile would be expected to show a gradual decrease with a half–life of about 8 days (physical half–life of iodine–131) or slightly less because of the diluting effect of plant growth.

Using the profile characteristics discussed above, it would appear that at some time between the July 13 and July 18 lettuce sampling dates deposition occurred, resulting in about a three–fold increase in iodine–131. There is no evidence of any deposition of activity during the July 18–27 interval in view of the fact that the observed decrease approximates a 6–day half–life. However, a combination of deposition and washoff during the interval cannot be ruled out. The much greater relative decrease observed between July 27 and August 6 may be accounted for by plant growth, washoff, and/or experimental uncertainties besides the normal decay of iodine–131.

It is interesting to note that the strontium–90 values for lettuce also indicate nearly a three–fold increase by deposition in the first time interval, July 13–18, and decreases in the remaining two intervals (see table 2). This observation, together with the low strontium–90

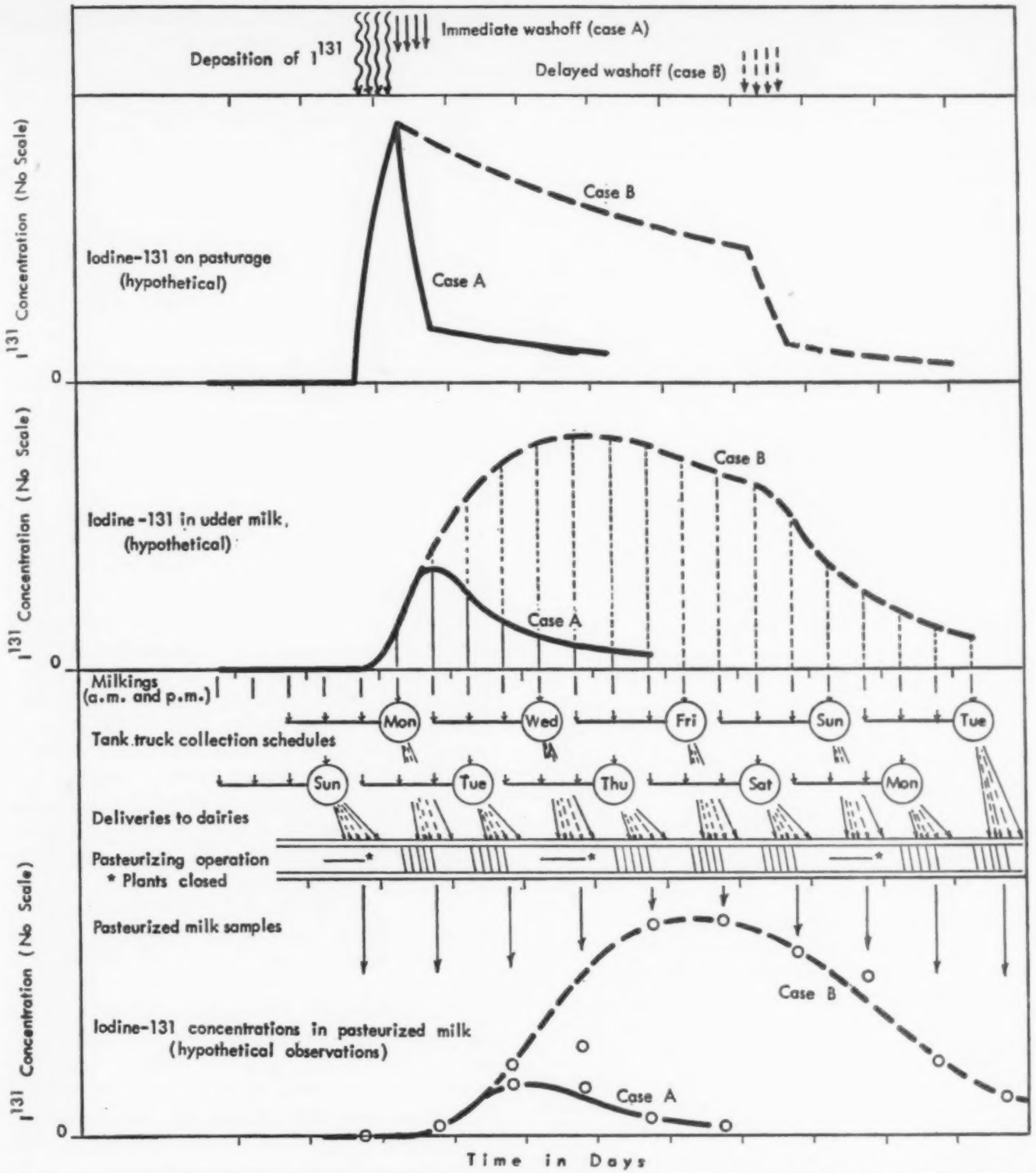


Figure 4.—HYPOTHESIZED TIME SEQUENCE RELATIONSHIPS FOR THE SALT LAKE CITY MILK COLLECTION AREA. This figure does not represent any given dates but is intended as an aid in visualizing approximate time relationships between initial fallout and appearance of iodine–131 in pasteurized milk using current Salt Lake City milk collection and pasteurizing schedules, and an assumed one-day effective half-life for iodine–131 in udder milk.

to total beta ratios[5] and the relatively short growing period for lettuce indicates that most of the strontium–90 measured in the lettuce samples probably was deposited during July.

Comparison Between Times of Appearance of Iodine–131 in Milk and Lettuce

Some comparability between the relative concentrations of iodine–131 in milk and leaf lettuce could be expected on the assumption that leaf lettuce acts similar to pasturage as a fallout (wet and dry) collector. However, it must be borne in mind that there is an inherent lag ranging from 12 hours to 2 days or more between fallout deposition and initial appearance of iodine–131 in pasteurized milk, but with the lettuce samples there was no time lag. Furthermore, the milk was collected from a large area, but the lettuce was collected in the immediate vicinity of Salt Lake City.

Figure 1 suggests that the lettuce values fit as expected with the milk profile, leading the latter by at least two days.

Comparison of Air and Precipitation Data with Iodine–131 in Milk

Comparisons are made in this section between air and precipitation data and the levels of iodine–131 in Salt Lake City milk during the first phases described above.

The first phase, July 8–12, representing the initial appearance of iodine–131 in milk (see figure 1 and table 1), appears to be associated with the gross beta peak evidenced by the July 8 RSN air sample in Salt Lake City. It is not certain, however, how much of the milk collection area was covered by the air mass having the beta activity. Some small dry fallout onto pasture grass is implied by the iodine–131 values in milk, since there was an apparent absence of precipitation in the milk collection area during the period July 7–10 (see figure 1). Localized rains in the area, however, cannot be ruled out. Another possible explanation for the presence of iodine–131 in milk is the inhalation of airborne iodine–131 by cows.

The second or plateau phase shown on the milk profiles, July 13–19, is more complex. The early part of the plateau could be due to the widespread rains over most of the milk collection area on July 12 and 13. Suggesting this is the combination of the fresh fission product activity detected in the RSN precipitation samples (see table 3) from Salt Lake City and the time sequence involved. Presumptively, these young fission products may have been present in the rain in other parts of the milk collection area as well. The later part of the plateau may also have been influenced by other more scattered rains on July 14, 15, and 16 or by dry fallout associated with the second peak of gross beta activity in air detected in Salt Lake City on July 16 and 17.

The third phase of the milk profile, July 20–26, showing a peak of iodine–131 activity, is difficult to ascribe wholly to any one causative factor. The initial sharp rise in iodine–131 in milk on July 20 appears to be circumstantially associated with the trace rains in several parts of the milk collection area on July 15–18 since the second peak of gross beta in air at Salt Lake City occurred during July 15–17. It is also possible that activity from the earlier rains of July 12, 13 and from dry fallout from the July 16, 17 gross beta in air peaks, may have contributed. No single factor can be identified which would account for the peak values for iodine–131 in milk shown on July 25 and 26. As was noted earlier, the iodine–131 activities of the lettuce samples would appear to indicate that no further deposition of iodine–131 took place in the vicinity of Salt Lake City after July 18. However, the 9–day interval between the average dates shown for the iodine–131 values for lettuce, plus the limited area embraced in the lettuce sampling, cannot rule out the possibility that deposition of iodine–131 took place in the milk collection area after July 18.

The decline of iodine–131 activity in milk after about July 26 suggests that the relatively widespread rains during the period July 24–26 and the more scattered rains throughout the rest of the month were relatively free of fresh fission product activity.

[5] The strontium–90: total beta ratio in lettuce increased from 0.1 percent on July 13 to 0.4 percent on August 6. A personal communication from Dr. E. P. Laug, Division of Pharmacology, Food and Drug Administration, indicates that samples with an age of 6 to 8 months have strontium–90: total beta ratios of 9 to 10 percent

Comparison of Iodine–131 in Lettuce with Air and Precipitation Data

The first group of lettuce samples, (July 13), were harvested during or after the widespread rains of July 12, 13 in which young fission product activity was observed at Salt Lake City. Hence, it is possible that much of the iodine–131 activity in the first lettuce samples was deposited by the rains of July 12 and 13. Although dry fallout from the July 8 gross beta peak must not be ruled out, the low iodine–131 values for milk up through July 12 give some evidence that the activity in lettuce which might be attributed to dry fallout is not great.

The second group of lettuce samples was harvested on July 18. This group showed the highest iodine–131 activity among the four groups. As with the later sharp rise of iodine–131 in milk (July 20), the July 18 average value for lettuce appears to be associated with the July 15–17 peak in air beta activity and the July 16 trace and light rains in the area immediate to Salt Lake City. The rains of July 13, 14 may have been of equal or more importance. The July 27 iodine–131 concentration in lettuce samples, as discussed earlier, gives no indication that any additional activity was deposited since the July 18 sampling.

Comparison of Air, Precipitation, and Milk Data with Nuclear Detonations

Based on U.S. Weather Bureau meteorological trajectories of nuclear tests given in this report, the RSN July 8 air peak of 595 $\mu\mu c/m^3$ and the initial appearance phase (July 8–12) for iodine–131 in milk would appear to have been due to the July 6 (Sedan) test (see figure 3). However, on the basis of available information, the possibility that the July 7 test (Little Feller II) might have made some contribution cannot be entirely discounted.

There was no distinguishable increase in gross beta activity in air as recorded by the RSN station in Salt Lake City on July 12 and 13. However, based on the July 11 test trajectory (see figure 3) it would appear that most of the gross beta activity in the July 12 and 13 precipitation (see table 3) probably originated with this test. Also, it is difficult to place a precise interpretation on the age of fission products in the precipitation samples for these two days. The peak of gross beta in air on July 15–17 can be most closely associated with the July 14 test, Small Boy, as evidenced by its trajectory. Based on time considerations, at least the first portion of the plateau stage for iodine–131 values in milk (July 13–19) must be largely attributed to the July 11 test (Johnie Boy). The later part of the plateau may have been partly due to precipitation or air contamination affected by Small Boy (July 14).

As pointed out earlier, the sharp rise of iodine–131 in milk on July 20, the beginning of the peak stage, was probably associated with the gross beta in air and the trace precipitation on July 16, 17, and 18. It seems reasonable, therefore, that the July 20 rise in milk is most closely associated with the July 14 Small Boy detonation.

From meteorological trajectories there is little evidence that the July 17 test, Little Feller I, made any marked contribution to the *peak stage* for iodine–131 in milk.

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(1) Utah State Department of Health and Salt Lake City Department of Health: *Utah's Experience with Radioactive Milk*, (October 1, 1962).

(2) U.S. Weather Bureau: *Daily Weather Map*, (July 7–12, 1962).

(3) U.S. Weather Bureau: *Climatological Data*, Utah, (July 1962).

(4) R. J. Garner: The Metabolism of Iodine and Strontium in Cows, *The Veterinary Record*, (December 26, 1959).

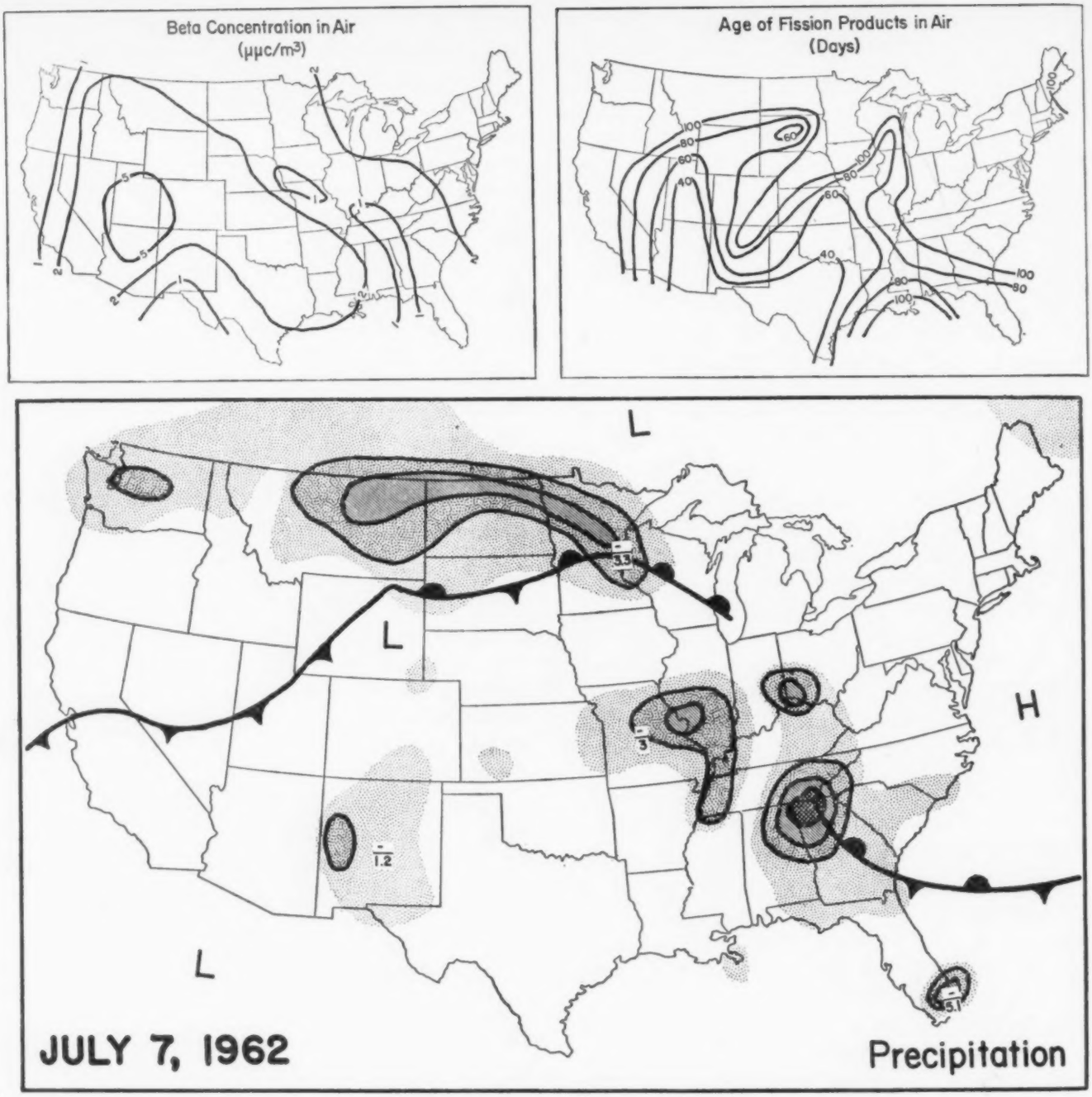
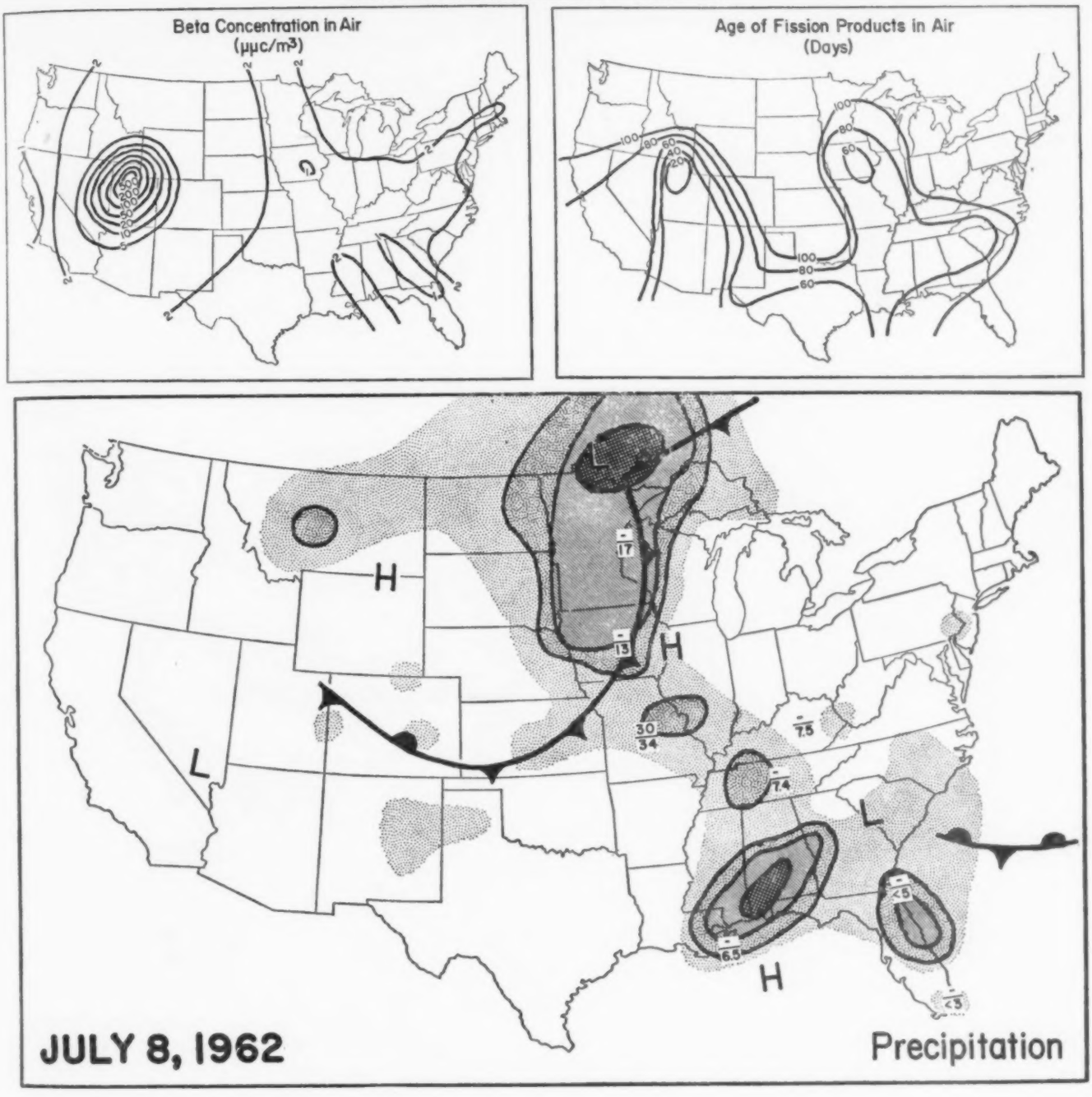


Figure 5.—COMPARISON OF DAILY FISSION PRODUCT CONCENTRATION AND AGE IN AIR WITH TOTAL PRECIPITATION



LEGEND

Fission Product Activity in Precipitation 24 Hour Period Ending 8:00 a.m. Local Time of the Date Indicated. (Same Period Applies to Air Maps Above)

>100 / 35

Top Number Indicates Age of Fission Products At Time of Collection (Example: Greater Than 100 Days)

Bottom Number Indicates Total Deposition of Beta Activity (Example: 35mμc/m²)

Total Precipitation During the 24 Hour Period Ending 1:00 a.m. EST of the Date Indicated

Trace–5mm

10–25mm

5–10mm

>25mm

Weather Symbols Showing Conditions At 1:00 a.m. EST

Cold Front

WarmFront

Stationary Front

Occluded Front

H High Pressure Area

L Low Pressure Area

Figure 5.—COMPARISON OF DAILY FISSION PRODUCT CONCENTRATION AND AGE IN AIR WITH TOTAL PRECIPITATION

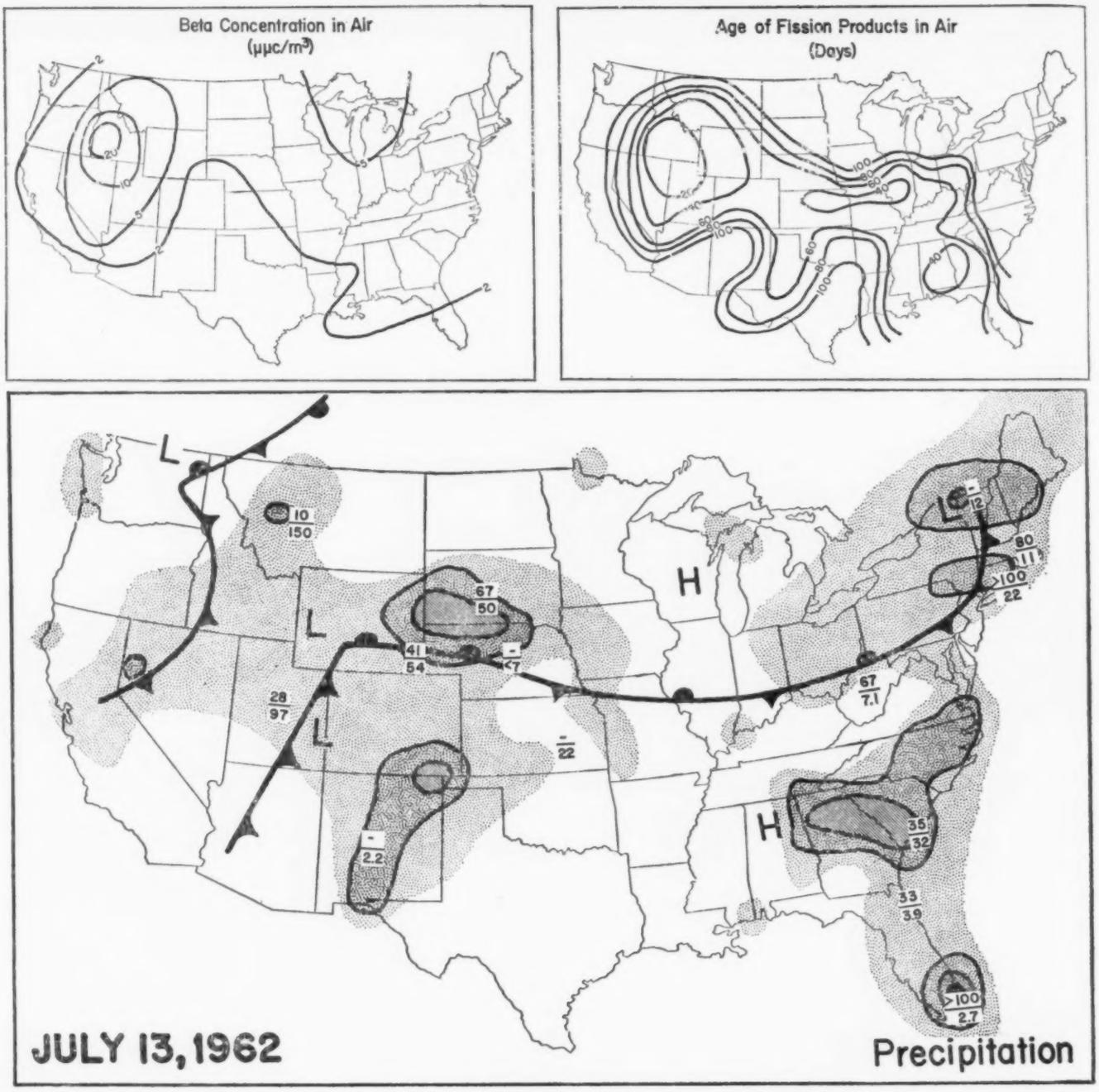
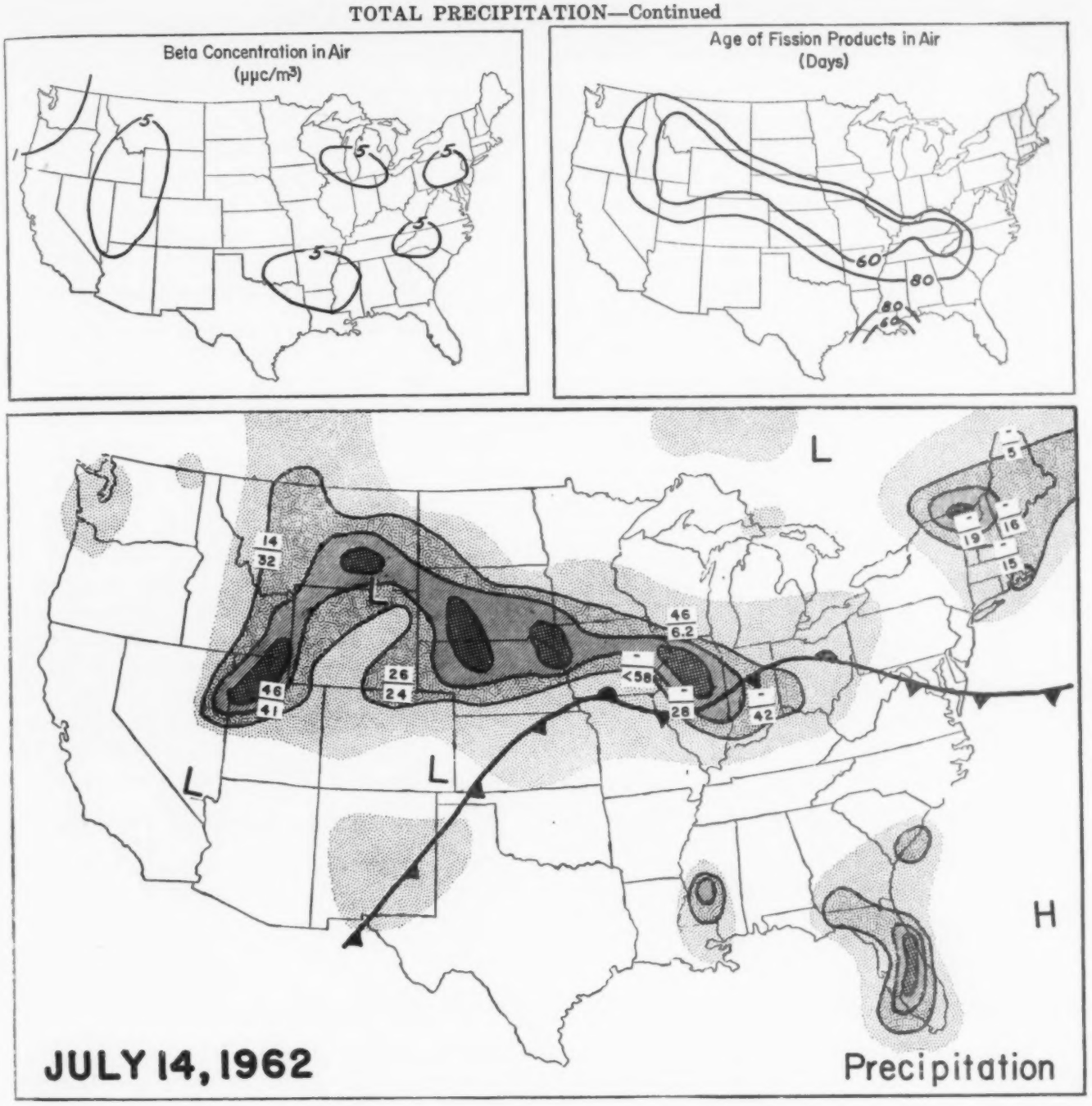


Figure 5.—COMPARISON OF DAILY FISSION PRODUCT CONCENTRATION AND AGE IN AIR WITH TOTAL PRECIPITATION



LEGEND

Fission Product Activity in Precipitation 24 Hour Period Ending 8:00 a.m. Local Time of the Date Indicated. (Same Period Applies to Air Maps Above)

>100 / 35

Top Number Indicates Age of Fission Products At Time of Collection (Example: Greater Than 100 Days)

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>25mm

Weather Symbols Showing Conditions At 1:00 a.m. EST

Cold Front

Warm Front

Stationary Front

Occluded Front

H High Pressure Area

L Low Pressure Area

Figure 5.—COMPARISON OF DAILY FISSION PRODUCT CONCENTRATION AND AGE IN AIR WITH TOTAL PRECIPITATION

Strontium–90 in Animal Feeds–1960, 1961, and 1962

Division of Pharmacology, Food and Drug Administration

A part of the continuing surveillance of radioactivity in foods by the Food and Drug Administration is concerned with the levels of radionuclides in animal feeds. The samples are analyzed in a manner similar to that for food items, as indicated in Section II of this issue. Data on the strontium–90 content of animal feeds appear in table 1.

The leafy types of animal feeds, such as alfalfa and lespedeza hays continue to show increased concentrations of strontium–90 over other types of feeds. The geographical and temporal distribution of strontium–90 in alfalfa is shown in table 2. It is clear that strontium–90 concentrations in this animal feed item have increased due to the resumption of nuclear weapons testing.

Table 3 shows that hays contain more strontium–90 on a weight basis than fodders, which could include stored feeds. It can be assumed that the fodders have been stored for a period of time. The effect of storage on animal feeds is demonstrated from this table in a limited manner. The hays are probably the most important single vector among the animal feeds for the introduction of strontium–90 into the food chain.

TABLE 1.—STRONTIUM–90 CONTENT OF ANIMAL FEEDS, 1960, 1961, 1962

Variety	Number samples	pc Sr^{90}/kg	
		Average	Range
Alfalfa hay	33	194	18 –779
Beet pulp	16	62	3.4–127
Corn ensilage	12	30	9.0– 64
Cottonseed meal	11	36	2.9– 95
Lespedeza hay	14	506	45 –960
Peanut hay	15	716	507 –912
Sorghum	4	157	34 –513

TABLE 2.—GEOGRAPHICAL AND TEMPORAL DISTRIBUTION OF STRONTIUM–90 IN ALFALFA

[pc/kg]

Pre-testing averages[a]		Post-testing averages[a]	
West	East	West	East
[b]81 (11)	176 (5)	366 (9)	517 (6)

[a] Samples harvested before Sept. 15, 1961 are designated "pre-test"; after this date, they are called "post-test".
[b] Numbers in parentheses refer to number of samples.

TABLE 3.—COMPARISON OF STRONTIUM–90 CONTENT OF HAYS AND FODDERS

	Number varieties	Number samples	Strontium–90	
			average (pc/kg)	Range (pc/kg)
Hays	3	62	391	18–960
Fodders	4	43	55	2.9–513

Previous coverage in *Radiological Health Data*:

Period	Issue
1959	*December 1960*
1960	*September 1961*
1960 and 1961	*December 1961*
1960	*April 1962*
1960, 1961, and 1962	*August 1962*
1961	*September 1962*

Reported Nuclear Detonations, November 1962

During November 1962, six U.S.S.R. and three U. S. nuclear detonations were announced by the Atomic Energy Commission. Among the U. S. tests was the last of the Operation Dominic series on November 4, after which the Johnston Island Test Area was deactivated.

Test number	Location	Date (1962)	Yield range	Type of test
REPORTED U.S.S.R. DETONATIONS				
59	Central Asia	November 1	Intermediate	High Altitude
60	Novaya Zemlya	1	Intermediate	Atmospheric
61	Novaya Zemlya	3	Intermediate	Atmospheric
62	Novaya Zemlya	3	Intermediate	Atmospheric
63	Semipalatinsk	4	Intermediate	Atmospheric
64	Semipalatinsk	17	Low	Atmospheric
REPORTED U. S. DETONATIONS				
93	Johnston Island	1	Submegaton	High Altitude
94	Johnston Island	4	Low	High Altitude
95	Nevada Test Site	27	Low	Underground

UNITS AND EQUIVALENTS

For the convenience of the *Radiological Health* (*RHD*) reader a selected list of units and equivalents is presented below.

Symbol	Name	Equivalent
Bev	billion electron volts	
cpm	count per minute	
dpm	disintegration per minute	
g	gram	
kg	kilogram	1 kg = 1000 gm = 2.2 pounds
km^2	square kilometer	
kvp	kilovolt peak	
m^3	cubic meter	1 m^3 = 1000 liters
ma	milliampere	
mas	milliampere-second	
Mev	million electron volts	
mi^2	square mile	
ml	milliliter	
mm	millimeter	precipitation: $mm = \frac{\mu\mu c/m^2}{\mu\mu c/\text{liter}} = \frac{\text{liter}}{m^2}$
mrad	millirad	
mrem	millirem	
mr/hr	milliroentgen per hour	
nc	nanocurie	1 nc = 1000 pc = 1 mμc = 10^{-9} curies
nc/m^2	nanocurie per square meter	1 nc/m^2 = 1 $m\mu c/m^2$ = 1,000 $\mu\mu c/m^2$ = 1 mc/km^2 = 2.59 mc/mi^2
pc	picocurie	1 pc = 1 $\mu\mu$c = 10^{-12} curies
r	roentgen	
$\mu\mu c$	micromicrocurie	1 $\mu\mu$c = 2.22 dpm

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